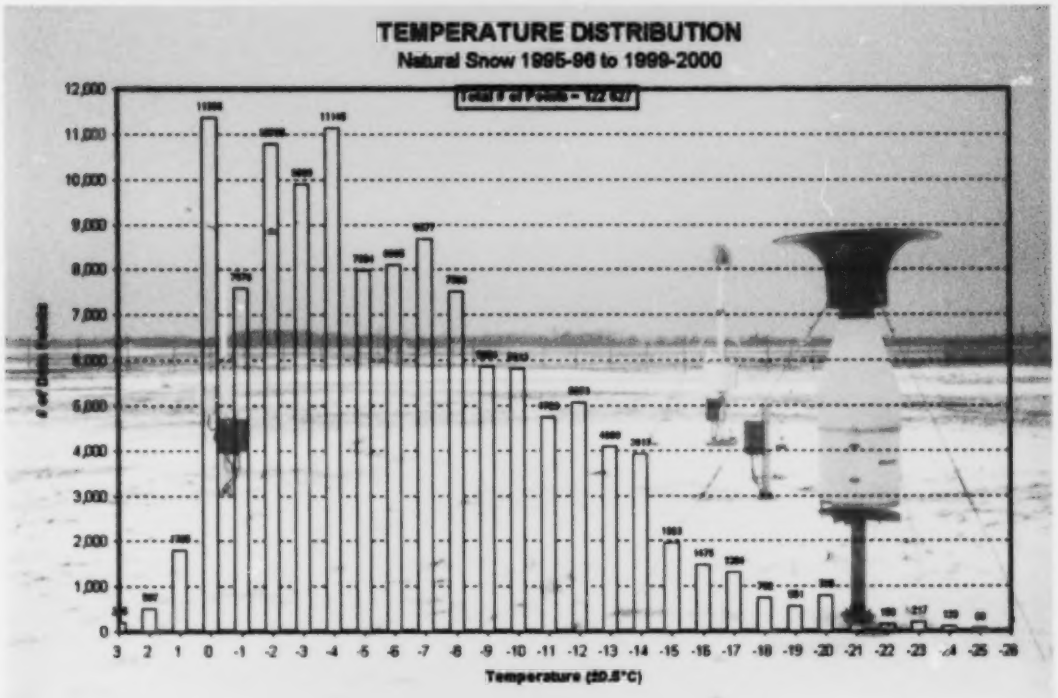
Snow Weather Data Evaluation (1995-2000)



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APS AVIATION INC.

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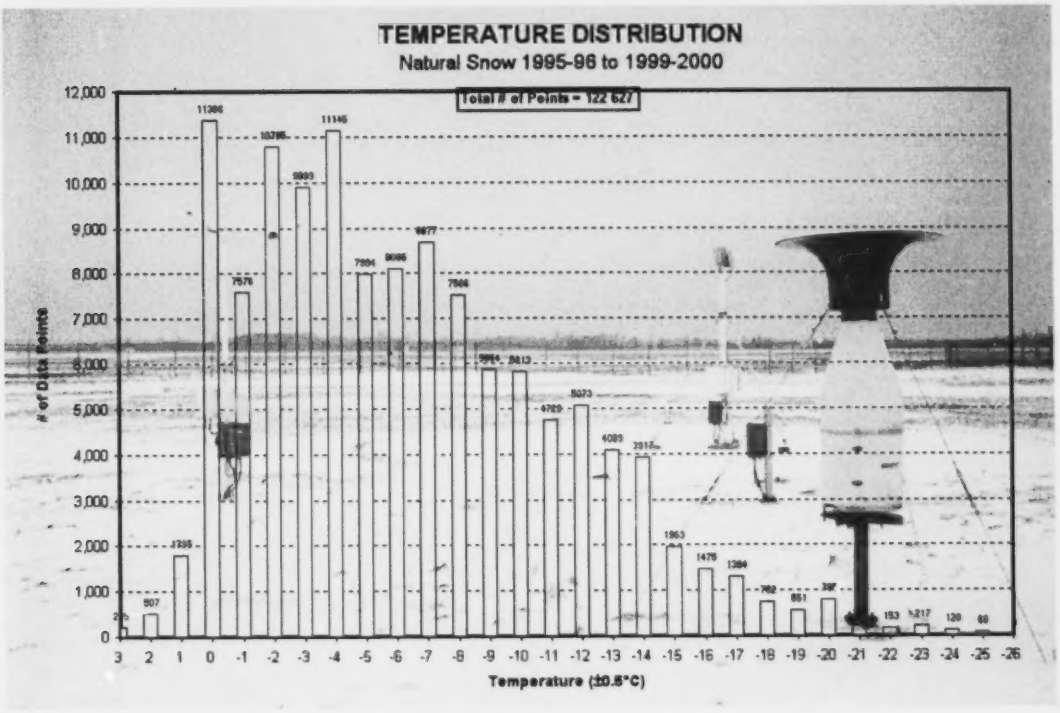
TP 13665E

Snow Weather Data Evaluation (1995-2000)



by

Medhat Hanna,
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Michael Chaput

APS AVIATION INC.

November 2000

Final Version 1.0

The contents of this report reflect the views of APS Aviation Inc. and not necessarily the official view or opinions of the Transportation Development Centre of Transport Canada.

The Transportation Development Centre does not endorse products or manufacturers. Trade or manufacturers' names appear in this report only because they are essential to its objectives.

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Un sommaire français se trouve avant la table des matières.

PREFACE

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. (APS) has undertaken a research program to advance aircraft ground de/anti-icing technology. The specific objectives of the APS test program are the following:

- To develop holdover time data for Type IV fluids using lowest-qualifying viscosity samples, and to develop holdover time data for all newly-qualified de/anti-icing fluids;
- To conduct flat plate holdover time tests under conditions of frost;
- To further evaluate the flow of contaminated fluid from the wing of a Falcon 20D aircraft during simulated takeoff runs;
- To determine the patterns of frost formation and of fluid failure initiation and progression on the wings of commercial aircraft;
- To evaluate whether the proposed locations of Allied Signal's wing-mounted ice sensors on an Air Canada CL65 are optimally positioned;
- To evaluate the second generation of the NCAR snowmaking system;
- To evaluate the capabilities of ice detection camera systems;
- To examine the feasibility of and procedures for performing wing inspections with a remote ice detection camera system at the entrance to the departure runway (end-of-runway);
- To reassemble and prepare the JetStar aircraft wing for mounting, to modify it to obtain cold-soak capabilities, and to conduct fluid failure tests in natural precipitation using the wing;
- To extend hot water deicing tests to aircraft in natural outdoor precipitation conditions, and to correlate outdoor data with 1998-99 laboratory results;
- To examine safety issues and concerns of forced air deicing systems; and
- To evaluate snow weather data from previous winters to establish a range of snow precipitation suitable for the evaluation of holdover time limits.

The research activities of the program conducted on behalf of Transport Canada during the 1999-2000 winter season are documented in nine reports. The titles of these reports are as follows:

- TP 13659E Aircraft Ground De/Anti-icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter;
- TP 13660E Evaluation of the Positioning of Surface Mounted Ice Detection Sensors on the Bombardier CL-65 Aircraft;
- TP 13661E A Second-Generation Snowmaking System: Prototype Testing;

- TP 13662E Ice Detection Sensor Capabilities for End-of-Runway Wing Checks: Phase 2 Evaluation:
- TP 13663E Hot Water Deicing of Aircraft: Phase 2;
- TP 13664E Safety Issues and Concerns of Forced Air Deicing Systems;
- TP 13665E Snow Weather Data Evaluation (1995-2000);
- TP 13666E Contaminated Aircraft Simulated Takeoff Tests for the 1999-2000 Winter: Preparation and Procedures; and
- TP 13667E Preparation of JetStar Wing for Use in Deicing Research.

This report, TP 13665E, has the following objective:

- To evaluate snow weather data over several recent winters to establish a range of snow precipitation rates suitable for the evaluation of holdover time limits.

This objective was met by acquiring and analysing winter weather data recorded by automated weather instruments at meteorological stations from six sites in Quebec, Canada. The data collected during the winters from 1995 to 2000 were statistically analysed to determine the cumulative probabilities of high precipitation rates in specific ambient air temperature intervals.

ACKNOWLEDGEMENTS

This research has been funded by the Civil Aviation Group, Transport Canada, and with support from the US Federal Aviation Administration. This program could not have been accomplished without the participation of many organizations. APS would therefore like to thank the Transportation Development Centre of Transport Canada, the Federal Aviation Administration, National Research Council Canada, Meteorological Service of Canada, and several fluid manufacturers. Special thanks are extended to US Airways Inc., Air Canada, the National Centre for Atmospheric Research, AéroMag 2000, Aéroports de Montreal, G. Vestergaard A/S, Hudson General Aviation Services Inc., Union Carbide, Cryotech, BFGoodrich, Cox and Company Inc., Fortier Transfert Ltée, and MTN Snow Equipment Inc. for provision of personnel and facilities and for their co-operation with the test program. APS would also like to acknowledge the dedication of the research team, whose performance was crucial to the acquisition of hard data. Special thanks are extended to Frank Eyre and Barry Myers of the Transportation Development Centre for their participation, contribution, and guidance in the preparation of this document.

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Research reports produced on behalf of Transport Canada for testing during previous winters are available from the Transportation Development Centre (TDC). Nine reports (including this one) were produced as part of this winter's research program. Their subject matter is outlined in the preface.

16. Abstract

APS Aviation Inc. undertook a study to evaluate precipitation rate/temperature data from previous winters to ascertain the suitability of the precipitation rate ranges used for holdover time evaluation. This report is a follow-up to the snow weather data report published in 1999 and encompasses all the data from that report. This study was performed to expand the available data set.

Data were acquired from Environment Canada from six automated weather stations in the province of Quebec, Canada, located in Dorval (Montreal), Quebec City, Rouyn, Pointe-au-Père, Frelighsburg, and High Falls. A total of 2014 hours of snowstorm data recorded between 1995 and 2000 and over 100 hours of freezing rain data were analysed. Included in the data set were over 700 hours of snow data from the 1999-2000 winter.

Data relating to the frequency of frost occurrences, and freezing fog and frost deposition rates measured during natural conditions are included in this report.

Based on the storm data subdivided by temperature ranges related to holdover time tables, it was observed that the precipitation rate limits used to establish the holdover times are satisfactory. Precipitation rates above 25 g/dm^2/h were found in all of the holdover time temperature ranges, including the -14 to -25°C range. The 95th percentile for precipitation rates was observed to be approximately 22 g/dm^2/h (5 percent of the precipitation rates were above 22 g/dm^2/h) for the total snow weather data. In the -14 to -25°C range, the 95th percentile was 22 g/dm^2/h.

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15. Remarques additionnelles (programmes de financement, titres de publications connexes, etc.)

Les rapports de recherche produits au nom de Transports Canada sur les essais réalisés au cours des hivers antérieurs peuvent être obtenus auprès du Centre de développement des transports (CDT). Le programme de la saison hivernale a donné lieu à neuf rapports (dont celui-ci). On trouvera dans la préface l'objet de ces rapports.

16. Résumé

APS Aviation Inc. a entrepris l'étude rétrospective de données sur les taux de précipitation et sur la température pour confirmer la validité des plages de taux de précipitation servant à déterminer la durée d'efficacité des liquides antigivrants. Le présent rapport fait suite au rapport des données de précipitations de neige publié en 1999 et il contient toutes les données de ce rapport. Cette étude avait pour but d'élargir l'ensemble de données.

Ces données ont été obtenues auprès d'Environnement Canada et provenaient des stations météorologiques automatiques de Dorval (Montréal), Québec, Rouyn, Pointe-au-Père, Frelighsburg et High Falls, dans la province de Québec, au Canada. Les données de neige résultaient d'un total de 2 014 heures d'observations entre 1995 et 2000. Quant aux données de pluie verglaçante, elles couvraient plus de 100 heures d'observations. L'étude comprenait également plus de 700 heures de données de neige recueillies durant l'hiver 1999-2000.

Le rapport contient des données sur les occurrences de gel et sur les taux de dépôt de givre et de précipitation de brouillard verglaçant, mesurés en conditions réelles.

À l'examen des données de précipitations de tempêtes de neige subdivisées par les plages de températures rapportées aux tables de durée d'efficacité, on a pu observer que les limites de taux de précipitation utilisées pour déterminer le temps d'efficacité étaient satisfaisantes. Des taux de précipitation au-dessus de 25 g/dm^2/h ont été observés dans toutes les plages de températures d'efficacité, y compris la plage de -14 °C à -25 °C. Pour l'ensemble des données concernant les taux de précipitation neigeuse, le 95^e percentile était d'environ 22 g/dm^2/h (5 % des taux de précipitation étaient au-dessus de 22 g/dm^2/h). Dans la plage de -14 °C à -25 °C, le 95^e percentile se situait également à 22 g/dm^2/h.

17. Mots clés	18. Diffusion
Neige naturelie, taux de précipitation, données météorologiques	Le Centre de développement des transports dispose d'un nombre limité d'exemplaires.

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EXECUTIVE SUMMARY

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a study to evaluate precipitation data (precipitation rate/temperature data) from several winters to confirm the suitability of the precipitation rate ranges used for holdover time evaluation.

Description and Processing of Data

A total of 2014 hours of storm data points were developed from precipitation gauge logs for natural snow, including 700 hours from the 1999-2000 data. Light freezing rain data, based largely on the 1998 ice storm, were used to develop over 100 hours of storm data. Data were acquired from Environment Canada from instruments located at Dorval Airport (Montreal, Quebec) and five other stations in the province of Quebec, Canada. The Dorval Airport data were collected over several winters; data from other stations were collected from the winters of 1997-98 to 1999-2000. Similar data were collected and analysed by Environment Canada at Toronto's Pearson Airport for two winters. Data relating to the frequency of frost occurrences, and freezing fog and frost deposition rates measured during natural conditions were also included in this study.

Results and Conclusions

Based on the data from this study, the precipitation rate ranges currently in use for developing the SAE holdover time tables are satisfactory. Precipitation rates above 25 g/dm^2/h were encountered in all temperature ranges, from above 0°C to the -14 to -25°C range; the high precipitation rates at cold temperatures were recorded mainly during a few snowstorms in the 1998-99 winter. The 95th percentile for precipitation rates was observed to be approximately 22 g/dm^2/h (5 percent of the precipitation rates were above 22 g/dm^2/h) for snow. In the -14 to -25°C range, the 95th percentile was also 22 g/dm^2/h. The 95th percentile precipitation rate from the limited freezing rain data was approximately 25 g/dm^2/h.

The data supplied from CR21X, a newer, modified data logger, require less smoothing and allow more accurate observation of fluctuating precipitation rates. More data of the type available from the CR21X equipment from a greater number of winters is needed to confirm the findings. The study should therefore be extended in upcoming winters to include data recorded from these automated precipitation gauges supported by Meteorological Service of Canada.

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SOMMAIRE

À la demande du Centre de développement des transports de Transports Canada, APS Aviation Inc. a entrepris l'étude rétrospective de données météorologiques (taux de précipitation, température) pour confirmer la validité des plages de taux de précipitation servant à déterminer la durée d'efficacité des liquides antigivrants.

Description et traitement des données

Un graphique des précipitations de tempêtes de neige a été établi à partir de relevés nivométriques couvrant un total de 2 014 heures, dont 700 heures pendant l'hiver 1999-2000. Les données de pluie légère verglaçante résultaient pour la plupart de 100 heures d'observations faites au cours de la tempête de verglas de 1998. Ces données, obtenues auprès d'Environnement Canada, provenaient de la station météorologique de l'aéroport de Dorval (Montréal, Québec) et de cinq autres stations du Québec. Les données de l'aéroport de Dorval couvraient plusieurs hivers, tandis que celles des autres stations ne couvraient que les hivers 1997-1998 à 1999-2000. Des données analogues ont été recueillies et analysées par Environnement Canada à l'Aéroport international Pearson de Toronto pour deux hivers. L'étude comprenait également des données sur les occurrences de gel et sur les taux dépôt de givre et de précipitation de brouillard verglaçant, mesurés en conditions réelles.

Résultats et conclusions

Selon les données analysées, les plages de températures actuellement utilisées par la SAE (Society of Automotive Engineers) pour établir ses tables de durées d'efficacité sont satisfaisantes. Des taux de précipitation au-dessus de 25 g/dm²/h ont été enregistrés dans toutes les plages de températures, de la plus haute (au-dessus de 0 °C) à la plus basse (-14 °C à -25 °C); les taux de précipitation élevés par temps froid ont surtout été enregistrés au cours de quelques tempêtes de neige, à l'hiver 1998-1999. Pour l'ensemble des données concernant les taux de précipitation neigeuse, le 95e percentile était d'environ 22 g/dm²/h (5 % des taux de précipitation étaient au-dessus). Dans la plage de -14 °C à -25 °C, le 95e percentile se situait également à 22 g/dm²/h. Dans la base restreinte de données de pluie verglaçante, le 95e percentile se situait à 25 g/dm²/h environ.

Les données fournies par le CR21X, un nouveau type d'enregistreur de données, exigent moins de lissage et permettent une observation plus précise de la fluctuation des taux de précipitation. Mais il faut acquérir un plus grand nombre de données telles que celles produites par le CR21X, couvrant un plus grand

nombre de saisons hivernales, pour confirmer les résultats obtenus. L'étude devrait donc se poursuivre encore quelques hivers, pour permettre l'analyse des données enregistrées par ces appareils automatiques utilisés par le Service de l'environnement atmosphérique.

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GLOSSARY

ADM	Aéroports de Montréal
AES	Atmospheric Environment Services
APS	APS Aviation Inc.
HOT	Holdover Time
IREQ	Institut de Recherche d'Hydro-Québec
OAT	Outside Air Temperature
READAC	Remote Environmental Automatic Data Acquisition Concept
TDC	Transportation Development Centre

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1. INTRODUCTION

At the request of the Transportation Development Centre of Transport Canada, APS Aviation Inc. undertook a study to further advance de/anti-icing technology. This report contains the results of an analysis conducted by APS Aviation in 1999-2000 on the evaluation of precipitation rate data. This report, though it focuses mainly on snow data, also includes a discussion of other precipitation conditions such as frost and fog. This study formed part of the 1999-2000 winter research program on deicing, as described in Section 5.1.5.1 of the detailed work statement shown in Appendix A.

Existing holdover times for snow were developed using lower and upper precipitation rates of 10 and 25 g/dm²/h for all air temperatures (0°C, -3°C, -14°C and -25°C). These rates had been considered extreme at temperatures of -14°C and -25°C because such high precipitation rates, although they do exist, were thought to be less frequent at these lower temperatures. Similarly, for other holdover time table precipitation conditions (e.g. frost), it was believed that the precipitation rates in snow diminish at colder temperatures. The 1998-99 precipitation data report indicated that the current holdover time rate limits are representative of natural snow conditions.

The purpose of this study was to:

- Evaluate weather precipitation data (precipitation rate/temperature data) over several recent winters to further substantiate the suitability of data ranges currently in use for the evaluation of upper and lower holdover time limits. This report encompasses all the data presented in the 1998-99 Transport Canada report, *Evaluation of Snow Weather Data for Aircraft Anti-Icing Holdover Times*, TP 13486E (1);

- Conduct fog deposition measurements outdoors, using a procedure devised during the past year, to determine the range of fog deposition rates that occur in natural conditions; and

- Collect frost deposition rates in natural conditions, in cold temperatures, to determine a deposition range for this condition.

Data relating to the frequency of frost occurrences, and freezing fog and frost deposition rates measured in natural conditions are included in this report in section 5.

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2. METHODOLOGY

This section describes the methods used to evaluate the weather data, which were collected to study the occurrences of high precipitation rates at low temperatures for natural snow and light freezing rain.

Holdover time tables were generated from data collected during the 1999-2000 winter test season. These tables, as well as descriptions of precipitation types, precipitation rates, rate limits, and the methods used to calculate holdover times will be presented in the Transportation Development Centre report *Aircraft Ground De/Anti-Icing Fluid Holdover Time and Endurance Time Testing Program for the 1999-2000 Winter* TP 13659E (2), to be published at a later date.

At the SAE Workshop on Laboratory Methods held in Montreal in 1997, the holdover time table guidelines were proposed for revision (3). It was proposed that the upper and lower precipitation rate limits for snow be reduced. This was suggested because there is a natural tendency toward reduced precipitation rates as outside air temperature drops, and it is generally contended that rate limits should reflect natural conditions as closely as possible.

The possibility of maintaining the currently accepted precipitation rate limits for snow – 10 and 25 g/dm²/h – was considered. After much debate, the precipitation rate limits shown in Table 2.1 were proposed for the lowest temperature ranges in conditions of snow.

TABLE 2.1
PROPOSED RATE LIMITS FOR NATURAL SNOW

Temperature Range	Holdover Time Evaluation Temperature	Precipitation Rate (g/dm²/h)	
		Proposed Upper Limit	Proposed Lower Limit
-3 to -14°C	-14°C	20	10
-14 to -25°C	-25°C	10	5
Below -25°C	(TBD by event)	5	2

However, despite the proposed changes and based on the data presented in the 1998-99 Transport Canada report *Evaluation of Snow Weather Data*, TP 13486E (1), the rate limits remained as shown in Table 2.2.

TABLE 2.2
CURRENT RATE LIMITS FOR NATURAL SNOW

Temperature Range	Holdover Time Evaluation Temperature	Precipitation Rate (g/dm²/h)	
		Accepted Upper Limit	Accepted Lower Limit
-3 to -14°C	-14°C	25	10
-14 to -25°C	-25°C	25	10
Below -25°C	(TBD by event)	25	10

The data in this report are intended to further support the accepted precipitation rate limits.

2.1 Sources of Data and Test Sites

APS collected data from various sources extending back to the 1990-91 winter season. A summary of these sources is shown in Table 2.3. The precipitation rates analysed in this report were extracted from the following:

- Dorval READAC log for the years 1995 to 1999
- Data logs from 1998 to 2000 for three CR21X stations at Rouyn, Pointe-au-Père (Mont-Joli), and Ancienne Lorette (Quebec City)
- Data log from the Dorval Airport CR21X station from 1998 and 1999
- Data logs for the year 2000 from two additional stations located in High Falls (near Ottawa, Ontario) and Frelighsburg (Eastern Townships).

Each site is identified on a map of Quebec, Canada, shown in Figure 2.1. The data are included in Appendix B. Furthermore, two similar studies were conducted in 1995-96. One study was conducted by APS using data collected from three weather stations located around Montreal (included in Appendix C). Atmospheric Environment Services (AES) carried out a similar study using data collected at Lester B. Pearson International Airport in Toronto (included in Appendix D).

TABLE 2.3

SUMMARY OF WEATHER DATA

PROJECT #	YEAR	PLATE PPAN	READAC YUL	CR21X						CITY OF MONTREAL (Fisher/Porter)	OMBROMETER THIES	ETI	TIPPING BUCKET	YYZ
				WUY (Rouyn)	WTQ (Dorval)	WQB (Quebec City)	WYQ (Pointe-au-Père)	WFQ (Frelighsburg)	XHF (High Falls)					
	1990/91	Test period											X[3]	
	1991/92	Test period								X[6]	X[3]			
	1992/93	Test period								X[6]	X[3]			
C1171	1993/94	Test period								X[1] (Three stations)	X[3] (Shielded)			
CM1222	1994/95	Test period	X[1]											
CM1283	1995/96	15 min	X[2]									X		X[4]
CM1338	1996/97	15 min	X[2]		X[5]									X[4]
CM1380	1997/98	5-15 min	X[2]	X[2]	X[2]	X[2]	X[2]							
CM1514	1998/99	5-15 min	X[2]	X[2]	X[2]	X[2]	X[2]							
CM1589	1999/00	5-15 min		X[2]	X[5]	X[2]	X[2]	X[2]	X[2]					

[1] Data analysed for Transport Canada in 1996.

[2] Data used for this report.

[3] Unusable data - precipitation rate determined by this gauge was always lower than other instruments.

[4] Analysis completed by AES at YYZ.

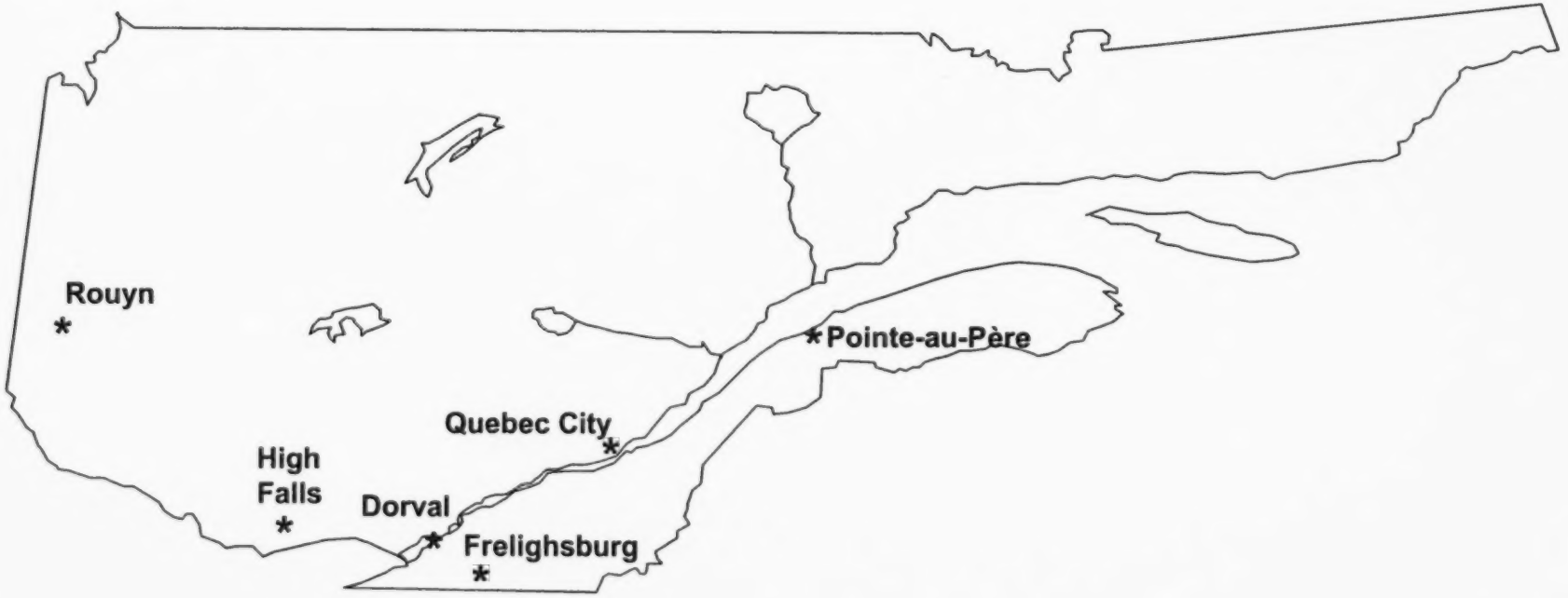
[5] Unusable data - scattered data (gauge was not shielded).

[6] Data archived.

FIGURE 2.1

MAP OF LOCATIONS OF PRECIPITATION GAUGES

Quebec, Canada



cm1589/reports/readac/map of quebec.dwg

2.2 Equipment

The Remote Environmental Automatic Data Acquisition Concept (READAC) precipitation gauge consists of a bucket partially filled with an antifreeze compound so that it effectively captures snow. A weighing transducer provides instantaneous displacement values of the bucket in terms of millimetres of precipitation. This shaft displacement is transmitted every 2.5 seconds and averaged every minute in an attempt to eliminate spurious data caused by gusts of wind and temperature-induced contraction and expansion of the sensor. The READAC instrument has a resolution of 0.5 mm (5 g/dm^2).

The CR21X station operates on the same principle as the READAC station, with an accuracy of 0.1 mm (1 g/dm^2). The station measures precipitation with a Fisher Porter precipitation gauge and the readings are logged with a CR21X data logger.

Precipitation rates tend to fluctuate rapidly during snowstorms. The weight resolution of the READAC stations is less accurate in measuring rapid changes. The data from the CR21X station required less smoothing before it could be interpreted. The increased resolution of the CR21X weighing transducer allows better observation of short periods of heavy precipitation.

2.3 Description of Analysis Methods

Precipitation rate data were averaged at intervals that correspond to three specified periods typically used in the holdover time tables: 6 minutes for Type I fluids, 20 minutes for Type II fluids, and 35 minutes for Type IV fluids. For natural snow, data were classified into the five temperature ranges: above 0°C, 0 to -3°C, -3 to -7°C, -7 to -14°C, and -14 to -25°C. For light freezing rain, data were classified into two ranges: 0°C to -3°C and -3 to -10°C.

Snowfalls at Dorval were tracked from 1995 to 2000, using the Monthly Meteorological Data Summary provided by Environment Canada. This summary includes meteorological data such as temperature, wind speeds and directions, dew point temperatures and humidity on an hourly basis, and precipitation type and total accumulation on a daily basis.

An example of the Monthly Meteorological Summary for Montreal is included in Appendix E. The last page of the summary (E-6) describes whether it snowed on a particular day and the first page (E-1) provides total snow accumulation for each day. Based on this information, the precipitation and temperature data were then extracted from READAC logs

on a minute-by-minute basis, and added to a database. The CR21X data were treated in a similar way.

Periods of snowfall were identified, using Environment Canada summaries, and snow accumulation data were added to the database along with ambient air temperatures. The five CR21X data loggers at Rouyn, Pointe-au-Père, Ancienne Lorette, High Falls, and Frelighsburg provided temperatures on an hourly basis. The temperatures were then linearly interpolated throughout the hour on a minute-by-minute basis.

Using a linear algorithm developed by APS, the total precipitation for each snowfall was averaged over time to produce a smooth curve. Figure 2.2 shows an output from the CR21X data logger recording the output from the precipitation gauges and the linearized data for a typical snowfall. The precipitation gauge output, sensitive to 1 g/dm², is plotted versus time to establish the periods of snowfalls. As shown in Figure 2.2, the period when snowfalls were interrupted for a long time was excluded from the analysis. Subsequent snowfalls were treated similarly. The first and last indications of snowfall (first and last 1 g/dm²) were excluded due to uncertainty about the precise start and end of the snowfall.

Periods of low-rate snow precipitation might have been overlooked because of long interruptions in bucket weight changes. It is difficult to establish whether these weight changes were due to constant low rate precipitation or long periods with no precipitation and short intervals of higher precipitation near the time of weight changes. The start and end of a snowstorm are difficult to determine because the snow might have started and ended gradually at slow rates or abruptly at high rates. Light snowfalls with total precipitation of less than 2 to 3 cm, over long periods of time (typically over six hours), were not included in the analysis.

The READAC and the CR21X data loggers record the bucket weight each minute. The precipitation rates are calculated based on the bucket weight and the time between readings. For each time interval the rate is calculated every minute using the following method:

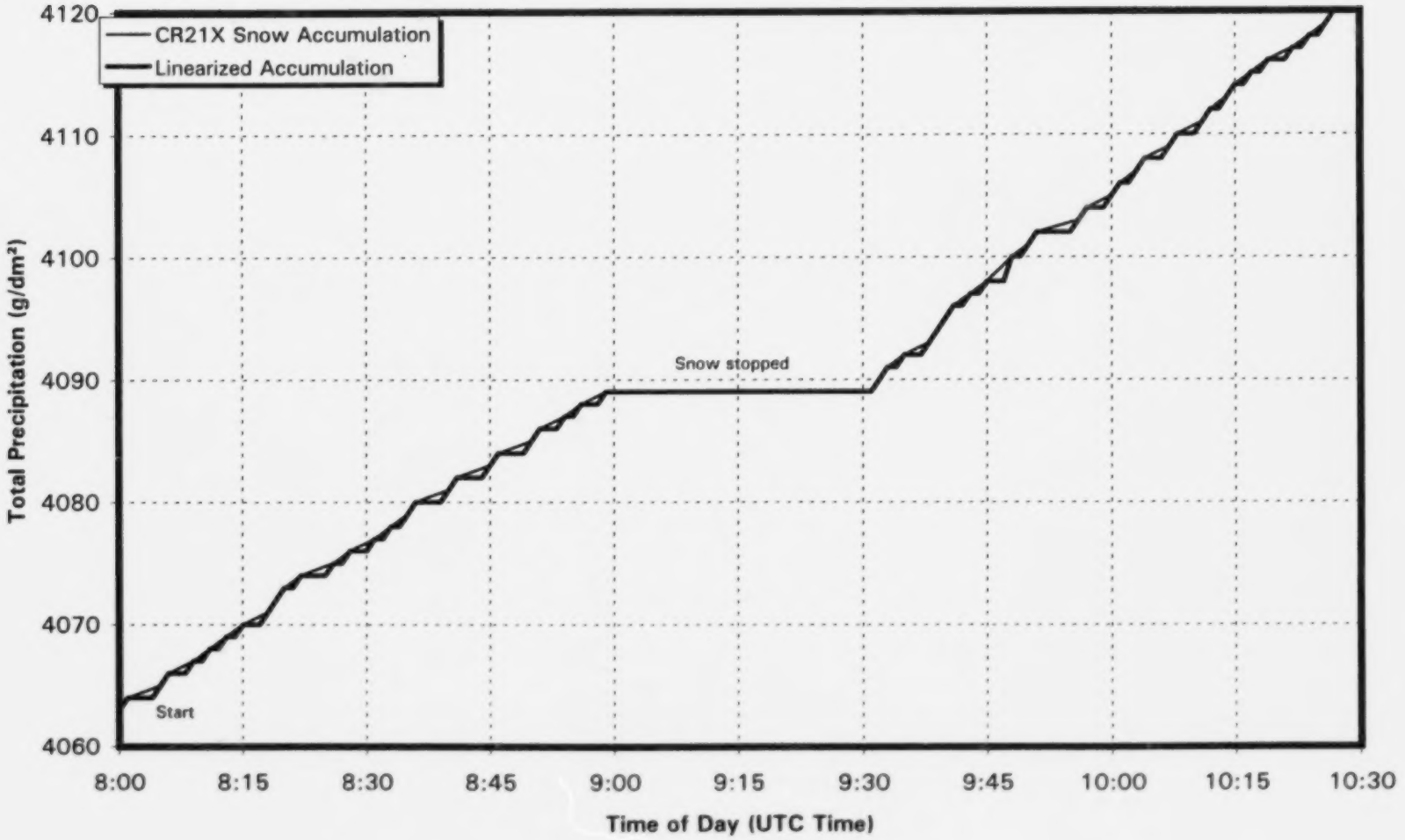
$$Rate_i = \frac{W_i - W_{i-1}}{\Delta time}$$

Where:

$Rate_i$	is the rate at a given time
W_i	is the linearized bucket weight at that time
W_{i-1}	is the linearized bucket weight one time interval before the given time
$\Delta time$	is the length of the time interval (6, 20 or 35 minutes)

FIGURE 2.2

CR21X PRECIPITATION GAUGE
CUMULATIVE AND LINEARIZED PRECIPITATION



cm1589/report/readac/CR21X Example.XLS

Once each rate was calculated, a temperature was associated with the rate, based on the time and day at which the rate was measured. All rate and temperature data were added to a database. The database contains all the calculated precipitation rates, classified by ambient temperature, for all sites included in the study. The database was then sorted by temperature range (Above 0°C, 0 to -3°C, -3 to -14°C, and -14 to -25°C) and the probability for each precipitation rate at each temperature range was determined using histograms and cumulative percentage.

3. DESCRIPTION AND PROCESSING OF NATURAL SNOW AND FREEZING RAIN DATA

3.1 Natural Snow

A total of 42 169 data points were collected for natural snow conditions during the 1999-2000 season from the five stations in Quebec. This represents approximately 700 hours of snowfall and an average of approximately 140 hours of snowfall at each station. As a result of improvements in the CR21X stations, most data collected during the past winter at stations other than Dorval were usable in this analysis. The Dorval data for 1999-2000 were unusable due to the bucket weight scatter. The distribution of new data points from all stations, sorted by temperature, is listed in Table 3.1.

TABLE 3.1
DISTRIBUTION OF DATA POINTS BY TEMPERATURE RANGE – NATURAL SNOW 1999-2000

Temperature Range	# of Data Points (1999-2000)
Above 0°C	4 425
Between 0 and -3°C	9 556
Between -3 and -7°C	12 952
Between -7 and -14°C	13 399
Between -14 and -25°C	1 837
Total	42 169

The distribution of data points for 1999-2000, by temperature and in histogram format, is shown in Figure 3.1.

A total of 120 869 data points were collected for natural snow conditions from 1995 to 2000. This represented, on average, more than 118 hours of snowfall per year per station, or 18 snowfalls of 6.5 hours each. The distribution of data points, by temperature range, is listed in Table 3.2.

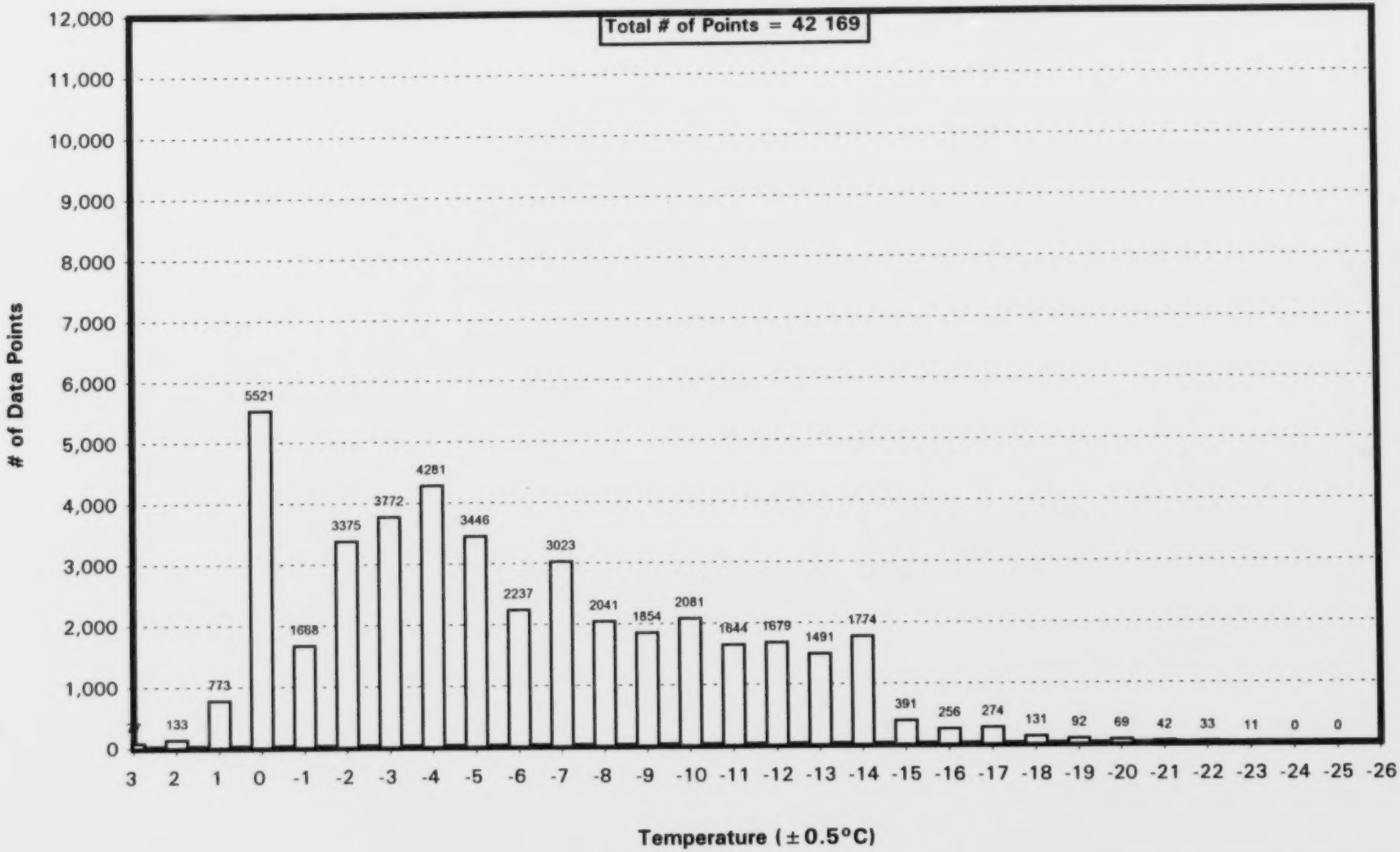
TABLE 3.2
DISTRIBUTION OF DATA POINTS BY TEMPERATURE RANGE – NATURAL SNOW 1995-2000

Temperature Range	# of Data Points (1995 to 2000)
Above 0°C	9 306
Between 0 and -3°C	27 840
Between -3 and -7°C	35 750
Between -7 and -14°C	38 761
Between -14 and -25°C	9 212
Total	120 869

FIGURE 3.1

TEMPERATURE DISTRIBUTION FOR WINTER 1999-2000

NATURAL SNOW



cm1589/reports/readac/Temperature Distibution
At: snow chart2000

Figure 3.2 shows the breakdown of total data points collected, from 1995-96 to 1999-2000, by temperature for natural snow. The following observations should be noted:

- 7.7 percent of the snowfalls occurred above 0°C temperature;
- 23.0 percent of the snowfalls occurred within the range of 0 to -3°C;
- 29.6 percent occurred between -3 and -7°C;
- 32.1 percent occurred between -7 and 14°C; and
- 7.6 percent occurred between -14 and -25°C.

3.2 Freezing Rain

Freezing rain data were developed from READAC logs, based mostly on the January 1998 ice storm, for a total of 6 367 data points. This represents approximately 106 hours of light freezing rain data. Other occurrences were not used because of a malfunction in READAC instruments. The distribution of these data, by temperature range, is shown in Figure 3.3 and summarized by temperature range in Table 3.3.

TABLE 3.3
DISTRIBUTION OF DATA POINTS BY TEMPERATURE RANGE – FREEZING RAIN

Temperature Range	# of Data Points
Above 0°C	171
Between 0 and -3°C	1 683
Between -3 and -10°C	4 513
Total	6 367

The following observations should be noted:

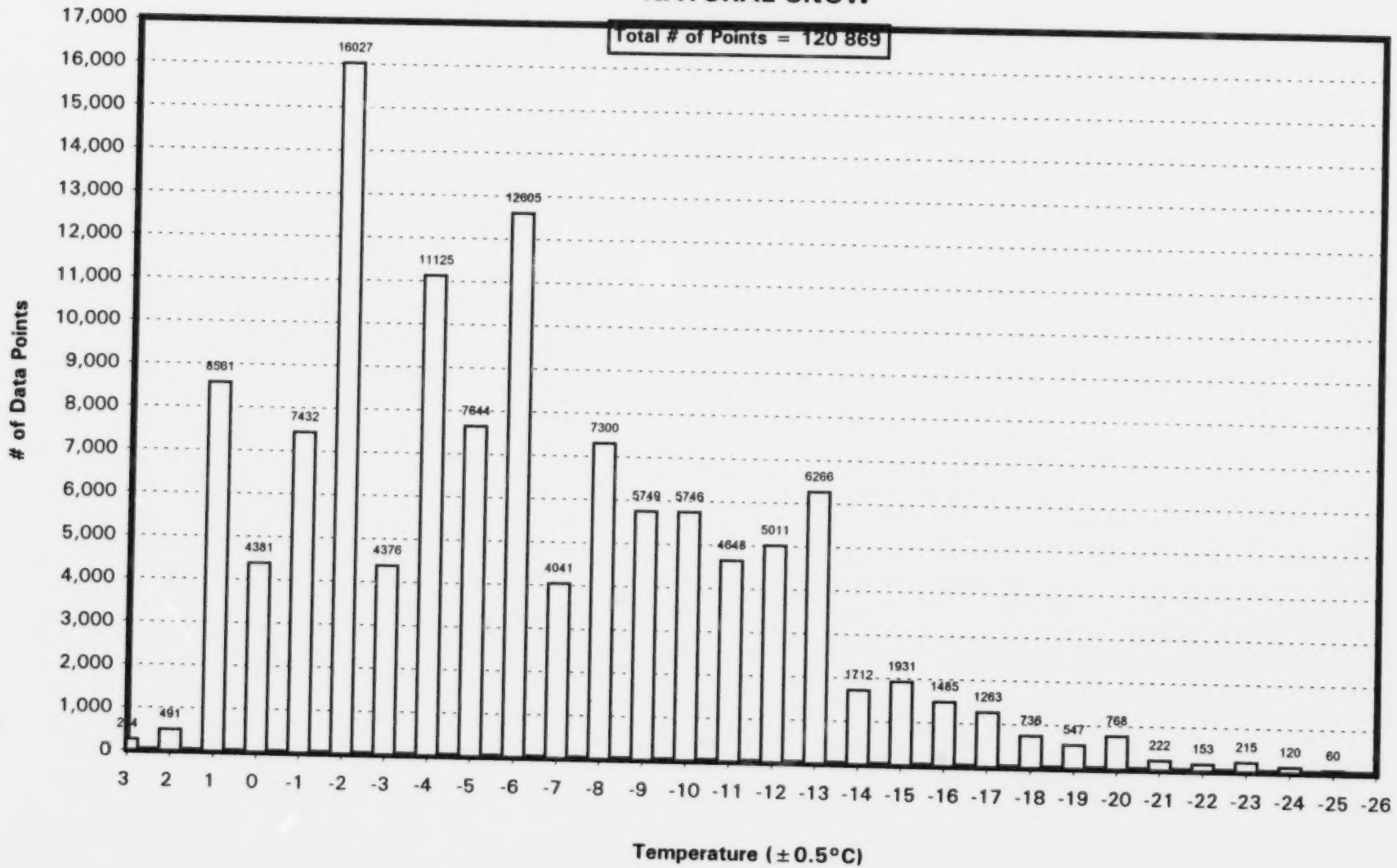
- Freezing rain did not occur at temperatures below -9°C and
- Over 60 percent of the freezing rain occurred at temperatures between -3 and -5°C.

These observations should not be used as a generalization of freezing rain occurrences because most of the data were limited to the January 1998 ice storm.

FIGURE 3.2

TEMPERATURE DISTRIBUTION FOR 1995-2000

NATURAL SNOW

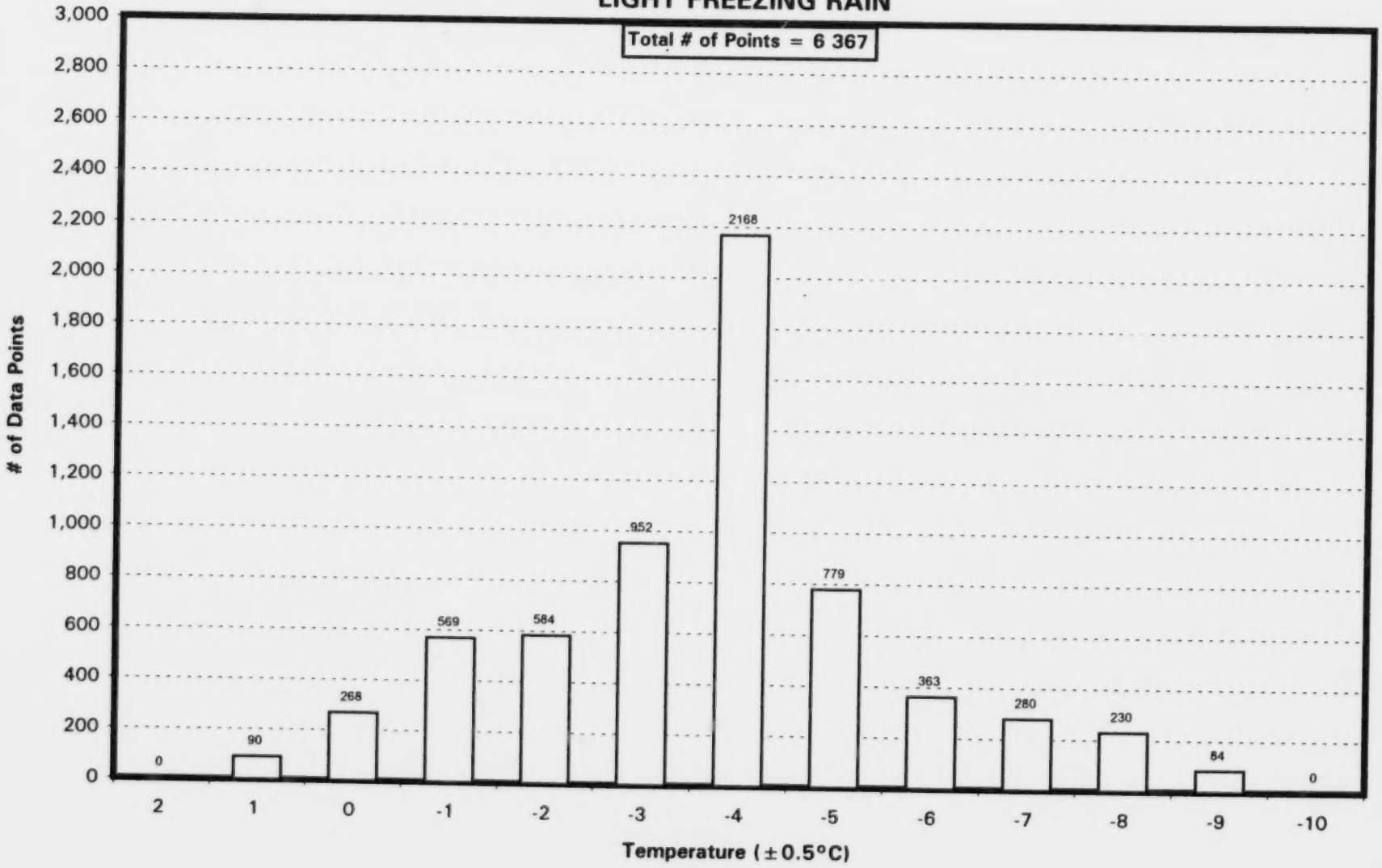


cm1589/analysis/readac/Temperature Distibution
At: snow chart 95-2000

FIGURE 3.3

TEMPERATURE DISTRIBUTION

LIGHT FREEZING RAIN



cm1589/report/readac/Temperature Distibution
At: ZR chart

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4. ANALYSIS AND OBSERVATIONS FOR NATURAL SNOW AND FREEZING RAIN

Precipitation rates were calculated from the weather data at 6-, 20-, and 35-minute intervals using a moving average calculated on a minute-by-minute basis. Table 4.1 shows minute-by-minute READAC data at Dorval Airport for a 37-minute period on December 14, 1995. Also shown are the 6-, 20-, and 35-minute averages computed using the linearized accumulation. The average snow rates, used as point data, were calculated by taking the snow accumulation during a specific time interval and dividing this value by the interval. The three intervals used for this analysis are represented in Table 4.1 by brackets in the column next to the "Linearized Total Snow Accumulation" column. The average snow rate was re-calculated every minute by moving the brackets down one time interval (one minute).

The snow weather data were graphed in two formats. In one, the number of occurrences of snow precipitation events was plotted against the precipitation rates for these events (Figure 4.1). The other (Figure 4.2) plots the cumulative probability of snow over all possible precipitation rates. The figures shown correspond to the temperature range of -3 to -7°C for 20-minute rate calculations. Both plots used the corresponding period to calculate average precipitation rates.

A complete set of plots for all temperature ranges and rate durations for natural snow and freezing rain is included in Appendix B.

The histogram in Figure 4.1 indicates that snow events with low precipitation rates occurred much more frequently than those with high precipitation rates for the temperature range shown.

The cumulative probability in Figure 4.2 indicates that over 96 percent of all the natural snow events in the data had precipitation rates below 25 g/dm^2/h for 20-minute rate intervals.

The 95th percentile criterion was used in the analysis conducted by AES in 1995 to determine the frequency of occurrence of precipitation rates. The same criteria were used by APS, and the results are described in the following subsections.

TABLE 4.1

SAMPLE OF READAC DATA AND ANALYSIS

Location	Date	Zulu Time	Temp (°C)	Type of Precip.	Total Snow Accumulation (g/dm²)	Linearized Total Snow Accumulation (g/dm²)		Moving Average Intervals		
								6 min	20 min	35 min
YUL	14/12/1995	21:16	-11.8	S-	40	40.00		9.38	9.38	10.08
YUL	14/12/1995	21:17	-11.7	S-	40	40.16		9.38	9.38	10.32
YUL	14/12/1995	21:18	-11.6	S-	40	40.31		9.38	9.38	10.56
YUL	14/12/1995	21:19	-11.6	S-	40	40.47		9.38	9.38	10.79
YUL	14/12/1995	21:20	-11.6	S-	40	40.63		9.38	9.38	11.03
YUL	14/12/1995	21:21	-11.6	S-	40	40.78		9.38	9.38	11.27
YUL	14/12/1995	21:22	-11.6	S-	40	40.94		9.38	9.38	11.50
YUL	14/12/1995	21:22	-11.5	S-	40	41.09		9.38	9.38	11.74
YUL	14/12/1995	21:23	-11.6	S-	40	41.25		9.38	9.38	11.97
YUL	14/12/1995	21:24	-11.6	S-	40	41.41		9.38	9.38	12.21
YUL	14/12/1995	21:24	-11.4	S-	40	41.56		9.38	9.38	12.45
YUL	14/12/1995	21:25	-11.4	S-	40	41.72		9.38	9.38	12.68
YUL	14/12/1995	21:25	-11.5	S-	40	41.88		9.38	9.38	12.92
YUL	14/12/1995	21:26	-11.5	S-	40	42.03		9.38	9.79	13.16
YUL	14/12/1995	21:26	-11.4	S-	40	42.19		9.38	10.20	13.39
YUL	14/12/1995	21:27	-11.4	S-	40	42.34		9.38	10.62	13.48
YUL	14/12/1995	21:28	-11.4	S-	40	42.50		9.38	11.03	13.57
YUL	14/12/1995	21:29	-11.4	S-	40	42.66		9.38	11.4	13.66
YUL	14/12/1995	21:30	-11.4	S-	40	42.81		9.38	11	13.75
YUL	14/12/1995	21:31	-11.4	S-	40	42.97			12.27	13.84
YUL	14/12/1995	21:31	-11.3	S-	40	43.13		9.38	12.68	13.93
YUL	14/12/1995	21:32	-11.3	S-	40	43.28		9.38	13.10	14.02
YUL	14/12/1995	21:32	-11.4	S-	40	43.44		9.38	13.51	14.11
YUL	14/12/1995	21:33	-11.4	S-	40	43.59		9.38	13.92	14.20
YUL	14/12/1995	21:33	-11.3	S-	40	43.75		9.38	14.34	14.29
YUL	14/12/1995	21:34	-11.3	S-	40	43.91		9.38	14.75	14.38
YUL	14/12/1995	21:34	-11.3	S-	40	44.06		9.38	15.17	14.46
YUL	14/12/1995	21:35	-11.3	S-	40	44.22		10.75	15.58	14.55
YUL	14/12/1995	21:35	-11.2	S-	40	44.38		12.13	15.99	14.64
YUL	14/12/1995	21:36	-11.2	S-	40	44.53		13.51	16.41	14.73
YUL	14/12/1995	21:36	-11.2	S-	40	44.69		14.89	16.56	14.82
YUL	14/12/1995	21:37	-11.2	S-	40	44.84		16.27	16.72	14.91
YUL	14/12/1995	21:37	-11.2	S-	45	45.00		17.65	16.88	15.00
YUL	14/12/1995	21:38	-11.2	S-	45	45.29		17.65	16.62	14.85
YUL	14/12/1995	21:39	-11.2	S-	45	45.59		17.65	16.36	14.71
YUL	14/12/1995	21:40	-11.2	S-	45	45.88		17.65	16.10	14.56
YUL	14/12/1995	21:41	-11.1	S-	45	46.18		17.65	15.85	14.41
YUL	14/12/1995	21:42	-11.1	S-	45	46.47		17.65	15.59	14.26
YUL	14/12/1995	21:43	-11.1	S-	45	46.76		17.65	15.33	14.12
YUL	14/12/1995	21:44	-11.1	S-	45	47.06		17.65	15.07	14.18
YUL	14/12/1995	21:45	-11.1	S-	45	47.35		17.65	14.82	14.25
YUL	14/12/1995	21:46	-11.1	S-	45	47.65		17.65	14.56	14.32
YUL	14/12/1995	21:47	-11.1	S-	45	47.94		17.65	14.30	14.39
YUL	14/12/1995	21:47	-11.0	S-	45	48.24		17.65	14.04	14.45
YUL	14/12/1995	21:48	-11.0	S-	45	48.53		16.79	13.79	14.51
YUL	14/12/1995	21:49	-11.0	S-	45	48.82		15.93	13.53	14.58
YUL	14/12/1995	21:50	-11.0	S-	45	49.12		15.07	13.27	14.64
YUL	14/12/1995	21:51	-11.0	S-	45	49.41		14.22	13.01	14.72
YUL	14/12/1995	21:52	-10.9	S-	45	49.71		13.36	12.76	14.79
YUL	14/12/1995	21:53	-10.8	S-	50	50.00		12.50	12.50	14.86

FIGURE 4.1

READAC AND CR21X ANALYSIS – NATURAL SNOW HISTOGRAM

-3 TO -7°C

20-Minute Rate Every Minute

1995-2000

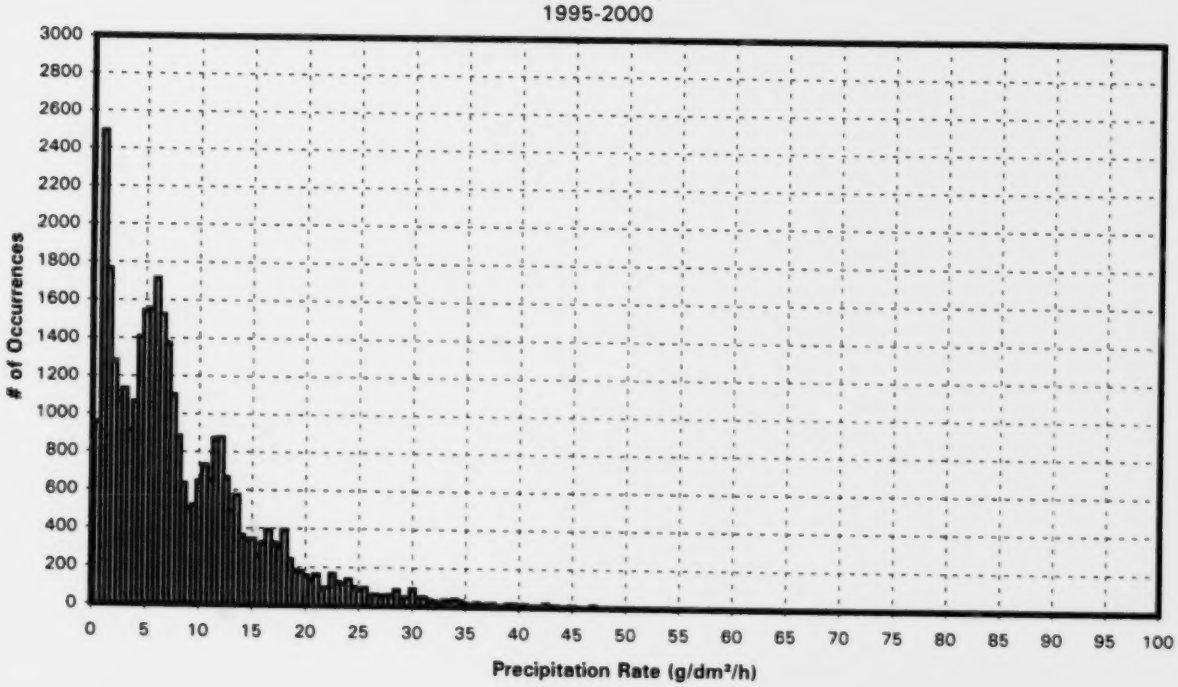


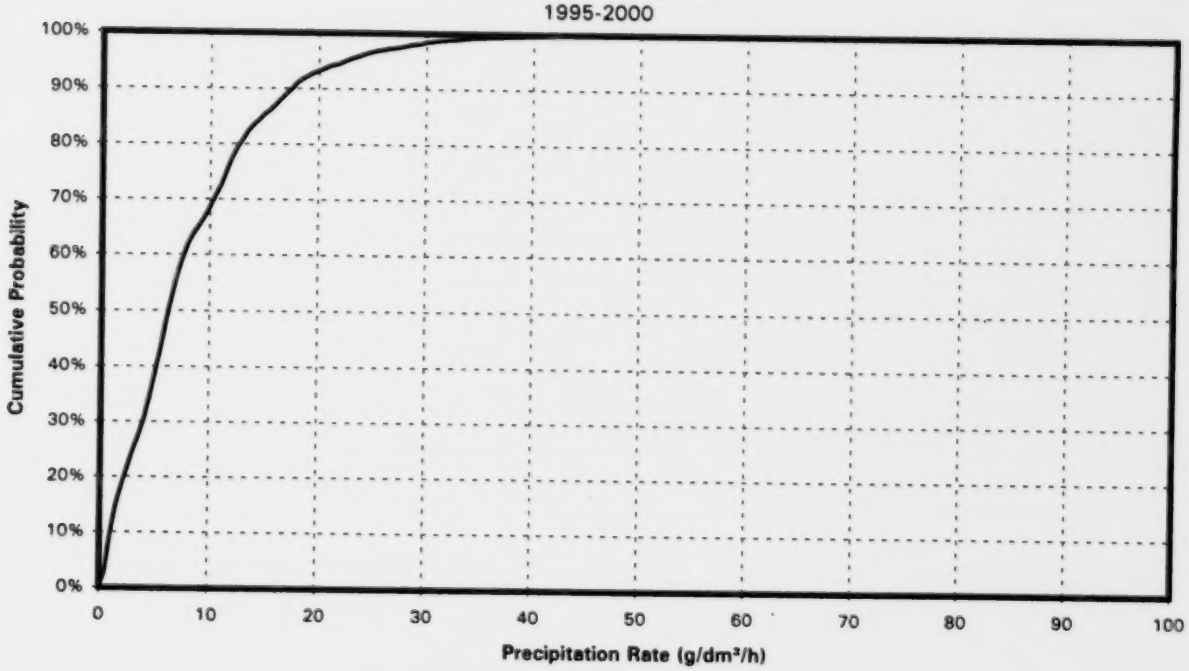
FIGURE 4.2

READAC AND CR21X ANALYSIS – NATURAL SNOW CHART

-3 TO -7°C

20-Minute Rate Every Minute

1995-2000



cm1589/report/readac/Example (-7°C)

4.1 Natural Snow

The 95th percentile for several temperature ranges for natural snow conditions is shown in Table 4.2 below:

TABLE 4.2
95TH PERCENTILE IN EACH TEMPERATURE RANGE – NATURAL SNOW

Temperature Range	95th Percentile Precipitation Rate ($g/dm^2/h$)		
	6 min	20 min	35 min
Above 0°C	20	19	18
0 to -3°C	19	18	18
-3 to -7°C	23	23	22
-7 to -14°C	23	24	24
-14 to -25°C	23	22	22

Each of the rates in the above table represents the rate below which 95 percent of all snowfalls occurred in a specific temperature range for a given rate duration. For example, in the temperature range of -3 to -7°C and for a duration of 20 minutes, the 95th percentile is 23 $g/dm^2/h$. This indicates that 95 percent of the 20-minute rates recorded between -3 and -7°C were equal to or below 23 $g/dm^2/h$. The percentages of occurrences when the precipitation rates were above 25 $g/dm^2/h$ are shown in Table 4.3 for all temperature ranges.

TABLE 4.3
PERCENTAGE OF HEAVY SNOW OCCURRENCES IN EACH TEMPERATURE RANGE – NATURAL SNOW

Temperature Range	Percent of Occurrences when Rate is above 25 $g/dm^2/h$			Percent of Data Points in Each Temperature Range
	6 min	20 min	35 min	
Above 0°C	2.3 %	2.5 %	2.6 %	7.7%
0 to -3°C	1.8 %	1.8 %	1.4 %	22.9%
-3 to -7°C	3.5 %	3.4 %	3.3 %	29.7%
-7 to -14°C	4 %	4.1 %	4.2 %	32.1%
-14 to -25°C	3.3 %	3.0 %	3.5 %	7.6%
			Total	100.0%

4.1.1 Relationship between Snow Data and SAE Holdover Time Tables

The probability of occurrence of snow events in each of the holdover time temperature ranges of the SAE Holdover Time tables is shown in Tables 4.4 and 4.5. Table 4.4 corresponds to the temperature ranges of Type I, and Table 4.5 corresponds to the ranges of Type II and Type IV fluids. There were no data available for natural snow conditions below -25°C. In addition, each of the tables provides the probability of snowfall as a function of light, moderate, and heavy snow.

For Type I, 70 percent of the probability of snow events occurred in the range of 0 to -10°C. Over 71 percent of the rates were classified as light snow (<10 g/dm²/hr). The probability of snow events for Type IV followed a similar pattern with 62 percent in the range of -3 to -14°C.

TABLE 4.4
TYPE I – PROBABILITY OF SNOW EVENT IN EACH HOLDOVER TIME CELL

Temperature (°C)	Light Snow (<10 g/dm²/h)	Moderate Snow (10 to 25 g/dm²/h)	Heavy Snow (>25 g/dm²/h)	Total
Above 0°C	5.2%	2.2%	0.2%	**7.7%**
0 to 10°C	50.5%	17.4%	1.9%	**69.8%**
Below -10°C	15.5%	6.0%	1.1%	**22.5%**
Total	**71.3%**	**25.6%**	**3.2%**	**100.0%**

TABLE 4.5
TYPE II AND TYPE IV – PROBABILITY OF SNOW EVENT IN EACH HOLDOVER TIME CELL

Temperature (°C)	Light Snow (< 10 g/dm²/h)	Moderate Snow (10 to 25 g/dm²/h)	Heavy Snow (> 25 g/dm²/h)	Total
Above 0°C	5.6%	1.8%	0.2%	**7.7%**
0 to -3°C	19.0%	3.6%	0.3%	**23.0%**
-3 to 14°C	44.2%	15.1%	2.3%	**61.7%**
Below -10°C	5.5%	1.8%	0.3%	**7.6%**
Total	**74.5%**	**22.4%**	**3.1%**	**100.0%**

4.2 Freezing Rain

The 95th percentile for two temperature ranges is shown in Table 4.6 for freezing rain:

TABLE 4.6
95TH PERCENTILE IN EACH TEMPERATURE RANGE – FREEZING RAIN

Temperature Range	95th Percentile Precipitation Rate (g/dm²/h)		
	6 min	20 min	35 min
0 to -3°C	29	26	23
-3 to -10°C	25	24	24

In freezing rain, the 95th percentile was near 24 g/dm²/h for the -3 to -10°C range and slightly higher, near 26 g/dm²/h, for the 0 to -3°C range.

4.3 Snow at Cold Temperatures

The general shape of the cumulative probability of occurrence curves at colder temperatures is similar to that of the curves drawn at other temperatures, as shown in Figure 4.3. The -7 to -14°C temperature interval represents the highest 95th percentile precipitation rate. This indicates that high rates do occur at cold temperatures.

The coldest temperature interval was divided into three smaller intervals (data shown in Appendix B):

- -14 to -18°C;
- -18 to -22°C; and
- -22 to -25°C.

High precipitation rates were more common in the -14 to -18°C range, but few high rate snowfalls were recorded in the other two ranges, as shown in Figure 4.4. It should be noted, however, that the 95th percentile was above 15 g/dm^2/h for all subdivided intervals. The percentages of occurrences when the precipitation rates were above 25 g/dm^2/h are shown in Table 4.7 for the subdivided intervals.

TABLE 4.7
PERCENTAGE OF HEAVY SNOW OCCURRENCES IN COLD TEMPERATURES – NATURAL SNOW

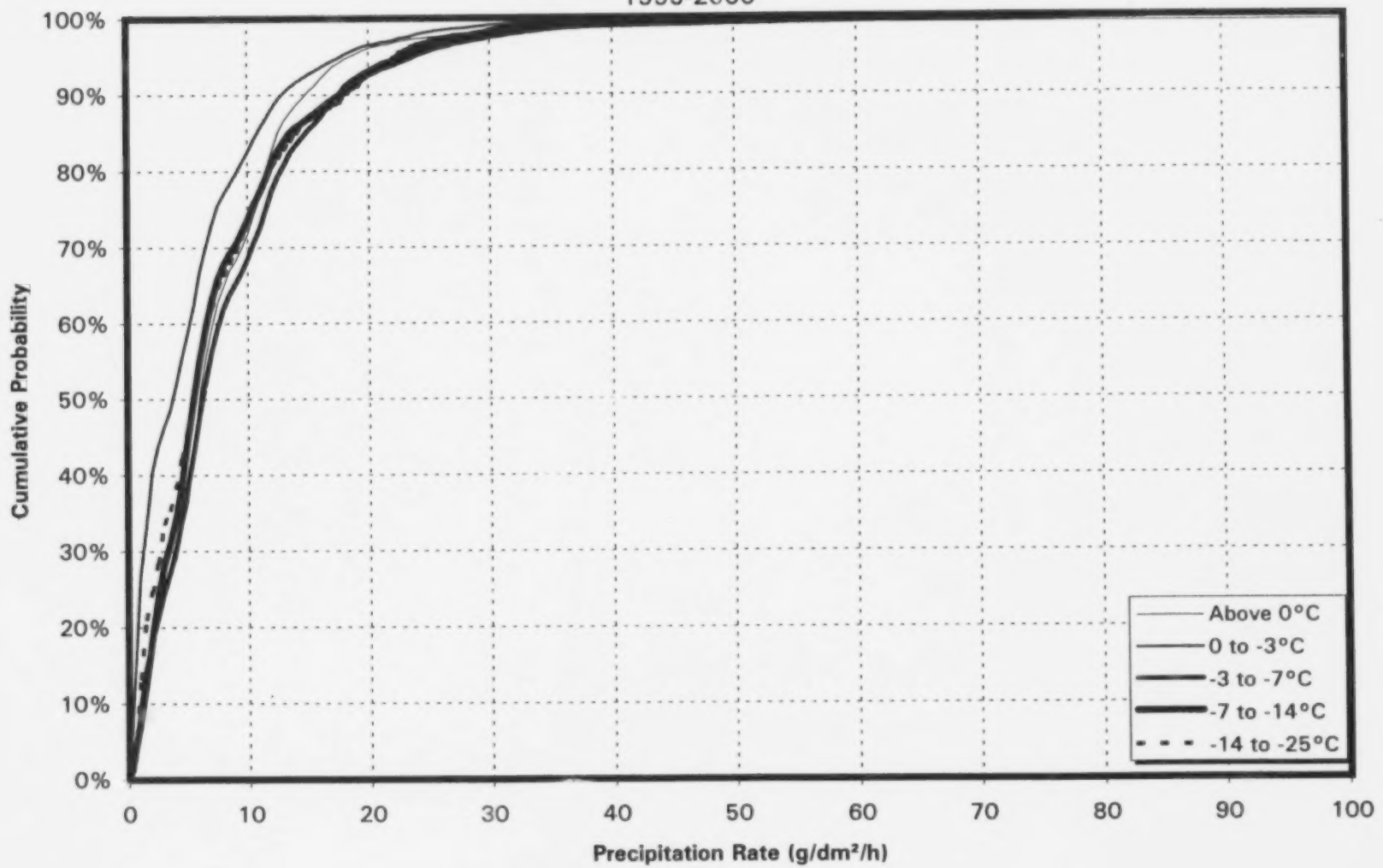
Temperature Range	Percent of Occurrences when Rate is above 25 g/dm^2/h			Percent of -14 to -25°C Data Points in Each Temperature Range	Percent of Total Data Points in Each Temperature Range
	6 min	20 min	35 min		
-14 to -18°C	4.2%	4.1%	4.7%	74.0%	5.6%
-18 to -22°C	0.5%	0%	0%	20.5%	1.6%
-22 to -25°C	1.5%	0.75%	0%	5.5%	0.4%
			Total	**100%**	**7.6%**

FIGURE 4.3

READAC AND CR21X ANALYSIS – NATURAL SNOW

20-Minute Rate Every Minute for all Temperature Ranges

1995-2000



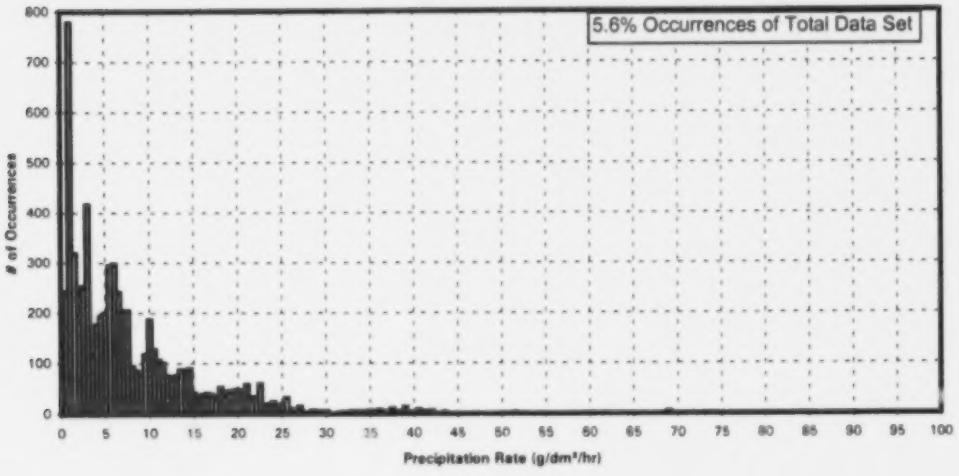
cm1589/reports/readac/All 20 minute rates

FIGURE 4.4

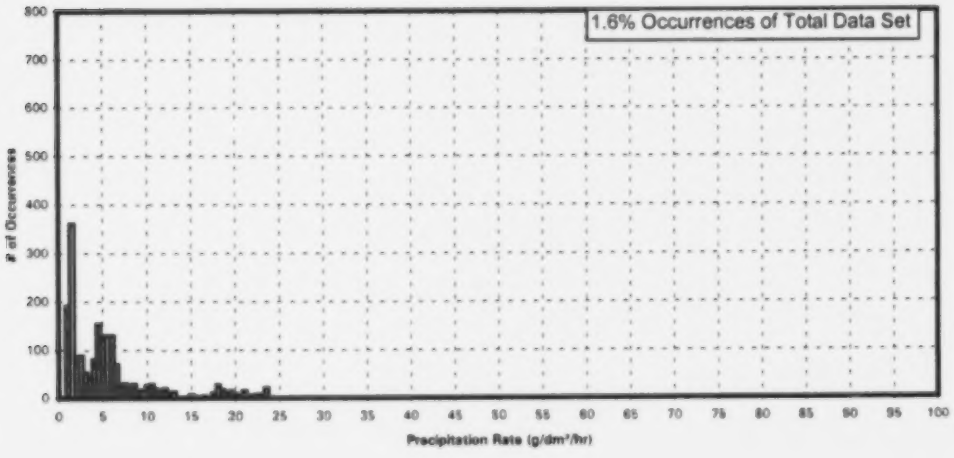
SUBDIVISION OF -14 TO -25°C SNOW DATA

20-Minute Rate Every Minute
1995-1999

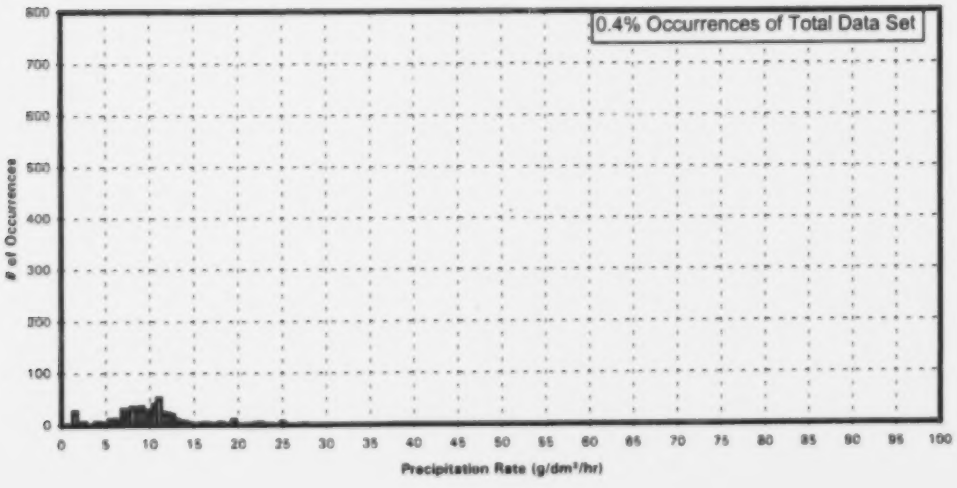
-14 TO -18°C



-18 TO -22°C



-22 TO -25°C



4.4 Comparing AES with APS 1995 to 2000 Snow Weather Data

A study of precipitation rate in each holdover time temperature interval was made in 1995 by AES. This study, based on data collected at an experimental site at Toronto's Pearson Airport, is included in Appendix D.

The graphs (Cumulative Probability versus Precipitation Rate) were reasonably similar in overall curve shape but not necessarily in exact values. For the temperature range of 0 to -3°C, the results of the AES study are very similar to those in this study. The 6-, 20-, and 35-minute rates are nearly identical in both studies. The 95th percentile was 16 g/dm^2/h in the AES report and 18 g/dm^2/h in this report.

In the -3 to -7°C temperature range, the general shape of the curves is not as similar as the 0 to -3°C curves. The findings of this study show that only 68.5 percent of precipitation is expected to be below 10 g/dm^2/h. The findings of the AES study suggest that 87 percent of precipitation will be at a rate lower than 10 g/dm^2/h. The curves from the APS and the AES studies show very little change in precipitation rate for the various time intervals, although a slight tendency toward higher rates is shown for shorter time intervals.

The 95th percentile rates, based on data collected from the READAC and CR21X stations, are 24 g/dm^2/h for the -7 to -14°C range. The 95th percentile precipitation rates for this temperature range are significantly higher than the AES study due to very high rates recorded during a least two specific snowfalls during the 1998-99 winter.

The -14 to -25°C range presents the largest variation in results between the two studies. The AES graphs indicate that snow precipitation rates in that temperature range are much lower than the other ranges. These findings do not match the results of this study. The data from the READAC and CR21X stations show very little difference in the probability versus precipitation rate curves for various temperature ranges.

Overall, these two data sets (AES and Snow Weather Data for 1995-2000) are similar enough to compare with each other for temperature ranges above -7°C. Below that temperature, the AES data do not contain any high rate precipitation points. The data collected by AES were recorded in Toronto. The average temperature is warmer in that region than in the regions where the APS data were collected. This resulted in colder ambient temperatures in the data analysed for this study.

Several reports have been published on temperature relationships and the occurrence of precipitation. These reports are listed in the references

section (4, 5, 6, 7, 8 and 9). They will be studied in detail in the upcoming season.

4.5 Comparison of 1993 to 1995 with 1995 to 2000 Snow Weather Data

Preliminary analysis of these two sets of data revealed that numerous data conversions are needed to help make substantial conclusions. Variations in scales between the two data sets can present other difficulties. The data presented in the 1993 to 1995 analysis were not separated into temperature ranges. The 95th percentiles, shown in Table 4.8, were approximated from the graphs presented in Appendix C.

From this data it can be observed that very high snowfall rates were recorded during the 1993-94 winter. The 95th percentile for the entire temperature range from 1993 to 1995 was 21 $g/dm^2/h$.

TABLE 4.8

SUMMARY OF 1993 TO 1995 SNOW WEATHER DATA

Date	Ambient Temperatures (°C)	95th Percentile Snowfall Rate (g/dm^2/h)
1993-1995	N/A	26
1993-1994	N/A	37
21-Dec-93	0.5	37
8-Jan-94	-18	11
14-Jan-94	-10	5
23-Jan-94	-16	13
27-Jan-94	-9	27
12-Feb-94	-8	17
23-Feb-94	-9	31
10-Mar-94	-5	19
27-Mar-94	0.2	31
1-Apr-94	-13	61
7-Apr-94	-1.3	16
1994-1995	N/A	21
7-Jan-95	-3	17
12-Jan-95	-14	20
4-Feb-95	-8	9
11-Feb-95	-9	14
16-Feb-95	-1	28
24-Feb-95	-0.2	11
27-Feb-95	-12	13
6-Mar-95	-7	25
8-Mar-95	-5	17

5. EVALUATION OF FOG AND FROST DEPOSITION RATES IN NATURAL CONDITIONS

This section contains a description of tests conducted to collect fog and frost deposition rates in natural conditions.

5.1 Special Study to Quantify Freezing Fog Deposition Rates

The objective of this study was to determine and correlate the range of deposition rates that occur naturally in fog with the 2 to 5 g/dm²/h range being used in environmental chambers. Fog deposition rates were to be collected on several occasions in periods of natural freezing fog. The procedure for fog deposition trials appears in Appendix F.

The test assembly included a precipitation collection pan inclined forward at 20° from the horizontal, wetted with Type IV fluid and mounted on the top of an automobile travelling at a top speed of 30 km/h for a pre-determined time interval. The weight of the precipitation collection pan was to be measured after each time interval so that the fog deposition rate could be calculated. Modifications to pan inclination, vehicle speed, and test duration were to be made pending the results of preliminary trials. One APS test team member would conduct the test.

One test was conducted during an overnight period following a day of intense rain. The fog was dense, and the visibility was estimated at approximately 150 metres (500 feet). No rain, other precipitation, or winds were noted during this test period. The outdoor temperature was 14°C.

The test assembly was placed on the top of the APS test team member's vehicle at a 10° angle for a period of exactly 30 minutes. During this time, a total of 13.4 kilometres were travelled, resulting in an average speed of 26.8 km/h. Eight grams of fog precipitation were collected, resulting in an average rate of precipitation of 1.29 g/dm²/h.

The obtained rate of 1.29 g/dm²/h is slightly below the lower precipitation rate limit currently used in holdover time testing in simulated conditions. No other tests were conducted during the past year.

5.2 Evaluation of Frost Deposition Rates in Natural Conditions

5.2.1 Objective

The objectives of this study were to determine:

- Frost deposition rates occurring naturally in northern climates; and
- Whether the rates of frost deposition were surface-finish dependent.

5.2.2 Description of Test Procedures

Frost deposition trials were conducted in Thompson, Manitoba. These tests were conducted on three separate occasions in January 2000 and April 2000.

The experimental procedure for frost tests on flat plates is shown in Appendix G. Four bare test surfaces with various compositions and/or finishes were prepared for the frost deposition trials. Each surface was pre-weighed to the nearest gram prior to being placed on a 10°-inclined test stand in active frost conditions and the start time was recorded. Following exposure to frost, the test surfaces were re-weighed. The final weights were calculated and recorded along with the end time of the test. Photo 5.1 shows the test set-up used in these trials.

Photo documentation of frost deposition trials was recorded using a 35 mm camera. Before and after photographs of each test surface were recorded.

5.2.2.1 Data Forms

One data form was employed during frost deposition trials:

- The Meteo/Plate Pan Data Form (Appendix G, Table 1) contains information on the weather conditions and was used to record deposition rates.

5.2.2.2 Equipment

The following equipment was required for the conduct of frost deposition tests:

- Plate A, 3.2 mm aluminium plate;

- Plate B, 1.6 mm aluminium painted plate (white);
- Plate C, Honeycomb carbon fibre composite plate;
- Plate D, Kevlar/Aramid honeycomb composite plate;
- Test stand;
- Weigh scale; and
- 35 mm camera.

5.2.2.3 Overview of Test Sessions

Frost deposition trials were conducted on three occasions in Thompson, Manitoba.

Run #1 was conducted overnight on January 22/23, 2000. The four test plates were weighed, placed on a test stand, and exposed to active frost for a six-hour period, from 11 p.m. to 5 a.m. The individual plates were re-weighed hourly. The ambient temperature at 11 p.m. was -29°C, and descended to -32°C at the end of testing.

Run #2 was conducted overnight on January 25/26, 2000. The test plates were weighed, placed on a test stand, and exposed to active frost for a seven-hour period, from 11 p.m. to 6 a.m. The individual plates were re-weighed hourly. The ambient temperature at 11 p.m. was -15°C, and descended to -24°C at the end of testing.

The final run was performed during the overnight period of April 3/4, 2000. The test plates were exposed for a seven-hour period of active frost, from 11 p.m. to 6 a.m. The individual plates were re-weighed hourly. The ambient temperature at 11 p.m. was -29°C, and descended to -32°C at the end of testing.

5.2.2.4 Description of Data Collected and Analysis

Frost deposition rates were calculated by dividing the difference between the start and end weights of the test surfaces (in grams) by the number of hours that the surfaces were exposed to frost conditions. The result was then divided by the area of the test surface (in dm^2). The frost deposition is expressed in $g/dm^2/h$.

The calculated frost deposition rates for the three test runs appear in Table 5.1.

TABLE 5.1

SUMMARY OF FROST DEPOSITION TRIALS

THOMPSON, MANITOBA

Run #	Temperature Range	Estimated Period of Active Frost	Average Rate (g/dm²/hr)			
			Plate A	Plate B	Plate C	Plate D
1	-29°C to -32°C	23:00 - 5:00	0.01	0.01	0.03	0.04
2	-15°C to -24°C	23:00 - 6:00	0.00	0.03	0.04	0.04
3	-11°C to -17°C	23:00 - 6:00	0.01	0.06	0.09	0.10

A = 3.2 mm aluminum plate
B = 1.6 mm painted aluminum plate
C = Honeycomb carbon fibre composite plate
D = Kevlar/Aramid honeycomb composite plate

cm1589/reports/readac/Frost Summary
1/16/03, 12:27 PM

Results from Run #1 indicate that frost deposition rates were in the range of 0.01 to 0.04 g/dm^2/h, depending on the test surface. The highest average deposition rate was experienced by plate D, the Kevlar/Aramid honeycomb composite plate (0.04 g/dm^2/h). The average rates observed on the 3.2 mm aluminium plate (plate A), the 1.6 mm white painted aluminum plate (plate B), and the carbon fibre honeycomb composite plate (plate C) were 0.01, 0.01, and 0.03 g/dm^2/h, respectively.

Results from Run #2 indicate that frost deposition rates were in the range of 0 to 0.04 g/dm^2/h, depending on the test surface. The highest deposition rate was experienced by plates C and D, the carbon fibre honeycomb composite plate, and the Kevlar/Aramid honeycomb composite plate. Both had deposition rates of 0.04 g/dm^2/h. The average rate observed on the 1.6 mm white painted aluminum plate (plate B) was 0.03 g/dm^2/h. No accumulation of frost was detected on the standard 3.2 mm aluminum plate (plate A).

Results from Run #3 showed average frost deposition rates in the range of 0.01 to 0.10 g/dm^2/h. The highest deposition rate was experienced by plate D, the Kevlar/Aramid honeycomb composite plate (0.10 g/dm^2/h). Photo 5.2 shows the frost deposition on Plate D. The average rates observed on the 3.2 mm aluminium plate (plate A), the 1.6 mm white painted aluminum plate (plate B), and the carbon fibre honeycomb composite plate (plate C) were 0.01, 0.06, and 0.09 g/dm^2/h, respectively.

The frost depositions obtained in these trials were visually inferior to those observed in Thompson during previous testing in 1996 (see Photos 5.3 and 5.4). The results of these tests are contained in TP 12897E *Evaluation of Frost Formations at Very Cold Temperatures* (10).

In general, the rates obtained in natural conditions at the colder temperatures (runs 1 and 2) agree with the values observed in frost calibration trials at IREQ, which were approximately 0.03 g/dm^2/h at -5°C. The rate depositions obtained in trials at Thompson and IREQ at -25°C are below the rate proposed for use in Aerospace Standard 5485, which is 0.06 g/dm^2/h.

5.3 Number of Occurrences of Frost Deicing at Dorval

Data representing the number of aircraft deicing events performed at the Dorval Airport were obtained for the 1995-1996 winter. These data were then separated into two categories: frost-related deicing and precipitation-related deicing. This classification was based on the airport deicing logs and the READAC station log. An example of the airport deicing log is shown in Table 5.2.

The pie chart shown in Figure 5.1 indicates that 1008 aircraft deicing events were attributed to frost. This represents 20.4 percent of the total deicing performed during the winter of 1995-1996. Figure 5.2 separates the frost deicing occurrences into various temperature ranges. The largest number of deicing events occurred between -15°C and -20°C.

Additional data were obtained from deicing operations during the 1999-2000 winter season at Dorval. AéroMag 2000 deicers at Dorval indicated that frost accounted for 31 percent of the deicing operations. Based on 30 years of data at Dorval, freezing drizzle, freezing rain, and freezing fog have been observed about 6 percent of the time that freezing precipitation is observed (i.e. when there is freezing precipitation, the precipitation falls as snow 94 percent of the time).

Based on this information, the estimate of frequency of deicing operations at Dorval is shown on the pie chart (Figure 5.3).

TABLE 5.2

EXTRACT OF DORVAL AIRPORT DEICING LOG

Aéroport de Dorval

Rapport de Dégivrage: Saison 1995-96

DATE	HEURE (time)	DÉGIVREUR (deicer)	COMP_AERIENNE (airline)	VOL (flt.)	AÉRONEF (aircraft)	SITE	TYPE	DÉGIVRANT (L) (deicing fluid)	CONC.
9/29/95	6:50	AIR CANADA	AIR CANADA	117	604	E	1	136.38	54%
9/29/95	7:15	AIR CANADA	AIR CANADA	781	202	E	1	90.92	54%
9/29/95	7:37	AIR CANADA	AIR CANADA	433	233	E	1	90.92	54%
10/30/95	17:00	CANADIEN	CANADIEN	108	A320	S	1	25.00	54%
10/31/95	6:45	AIR CANADA	AIR CANADA	117	601	E	1	345.49	30%
10/31/95	6:45	AIR CANADA	AIR ONTARIO	371	809	E	1	72.73	30%
10/31/95	6:50	AIR CANADA	AIR CANADA	825	234	E	1	154.56	30%
10/31/95	6:55	AIR CANADA	AIR CANADA	781	740	E	1	118.19	30%
10/31/95	7:00	AIR CANADA	AIR CANADA	770	735	E	1	90.92	30%
10/31/95	7:00	AIR CANADA	AIR CANADA	401	621	E	1	322.76	30%
10/31/95	7:00	CANADIEN	CANADIEN	961	A320	S	1	15.00	54%
10/31/95	7:05	AIR CANADA	AIR CANADA	740	737	E	1	104.56	30%
10/31/95	7:30	AIR CANADA	AIR CANADA	433	228	E	1	150.01	30%
10/31/95	7:59	DELTA	DELTA	611	MD88	W	1	94.64	54%
10/31/95	8:00	AIR CANADA	AIR CANADA	403	604	E	1	331.85	30%
10/31/95	8:00	AIR CANADA	AIR CANADA	928	208	E	1	131.83	30%
10/31/95	8:00	NORTHWEST	NORTHWEST	1254	DC9-30	W	1	113.65	54%
10/31/95	8:29	DELTA	DELTA	2089	727	W	1	94.64	54%
10/31/95	8:55	AIR CANADA	AIR CANADA	920	210	E	1	140.92	30%
11/1/95	16:00	AIR CANADA	AIR CANADA	787	734	E	1	104.56	30%
11/1/95	16:00	AIR CANADA	AIR CANADA	787	734	E	1	104.56	30%
11/1/95	17:00	AIR CANADA	AIR CANADA	139	214	E	1	163.65	30%
11/1/95	17:00	AIR CANADA	AIR CANADA	139	214	E	1	163.65	30%
11/1/95	17:30	AIR CANADA	AIR CANADA	135	607	E	1	213.66	30%
11/1/95	17:30	AIR CANADA	AIR CANADA	175	201	E	1	140.92	30%
11/1/95	17:30	AIR CANADA	AIR CANADA	135	607	E	1	213.66	30%
11/1/95	17:30	AIR CANADA	AIR CANADA	175	201	E	1	140.92	30%
11/1/95	18:00	AIR CANADA	AIR CANADA	423	507	E	1	390.95	30%
11/1/95	18:00	AIR CANADA	AIR CANADA	155	227	E	1	154.56	30%
11/1/95	18:00	AIR CANADA	AIR CANADA	155	227	E	1	154.56	30%
11/1/95	18:00	AIR CANADA	AIR CANADA	423	507	E	1	390.95	30%
11/1/95	18:05	DELTA	DELTA	637	MD88	N	1	189.27	54%
11/1/95	18:10	AIR CANADA	AIR CANADA	144	222	E	1	159.11	30%
11/1/95	18:10	AIR CANADA	AIR CANADA	144	222	E	1	159.11	30%
11/1/95	18:15	AIR CANADA	AIR CANADA	572	709	E	1	122.74	30%

FIGURE 5.1

FREQUENCY OF FROST DEICING EVENTS

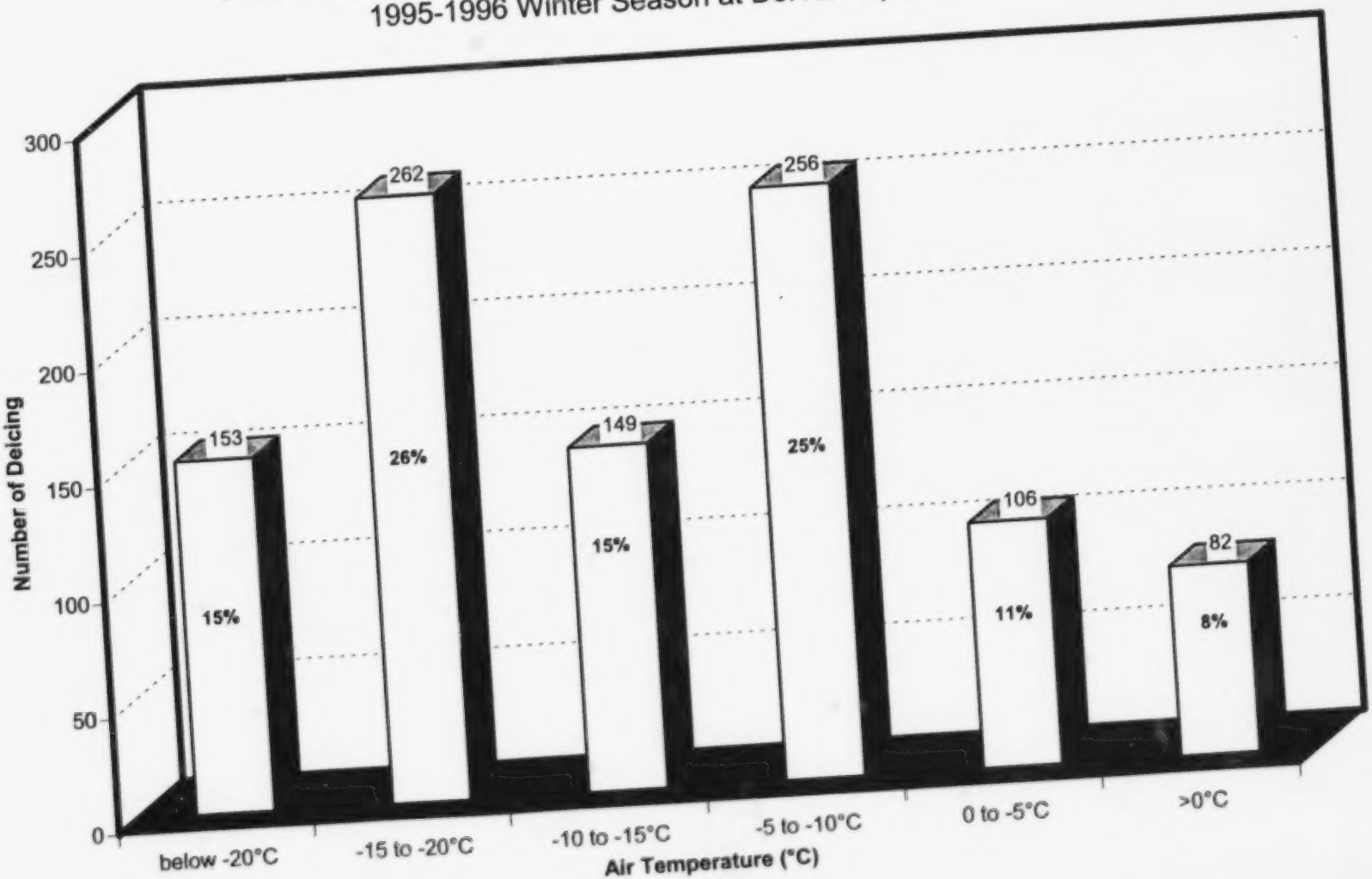
1995-1996 Winter Season at Dorval Airport

cm1589/reports/readac/Frost Deicing (Pie Chart)
At: Pie

FIGURE 5.2

FREQUENCY OF FROST DEICING BY TEMPERATURE

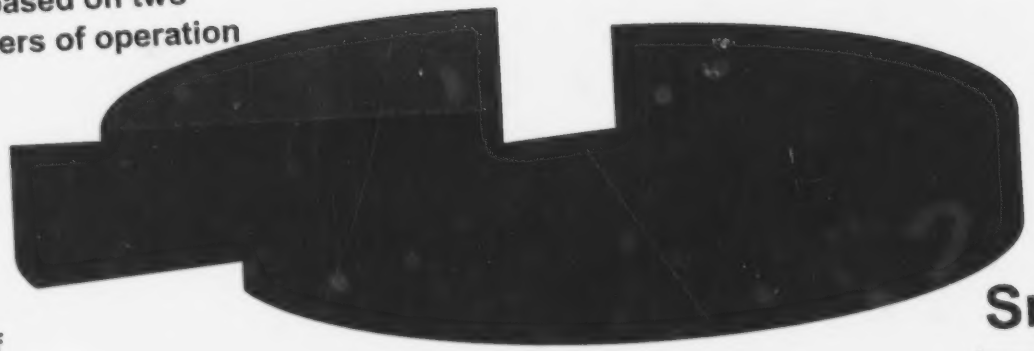
1995-1996 Winter Season at Dorval Airport



cm1589/reports/readac/Frost Deicing (Bar Chart)

FIGURE 5.3

ESTIMATE OF FREQUENCY OF DEICING OPERATIONS AT DORVAL


Frost 25%
based on two winters of operation
ZD, ZR, Zfog 5%
based on 30 years of wx observation
Snow 70%
based on 30 years of wx observation

cm1589/reports/reaadac/Est. of Freq.

Photo 5.1
Test Set-up for Frost Deposition Trials

Photo 5.2
Frost Accumulation on the Kevlar/Aramid Composite Plate

Photo 5.3
Edge View of Frost on Dark Blue Painted Surface

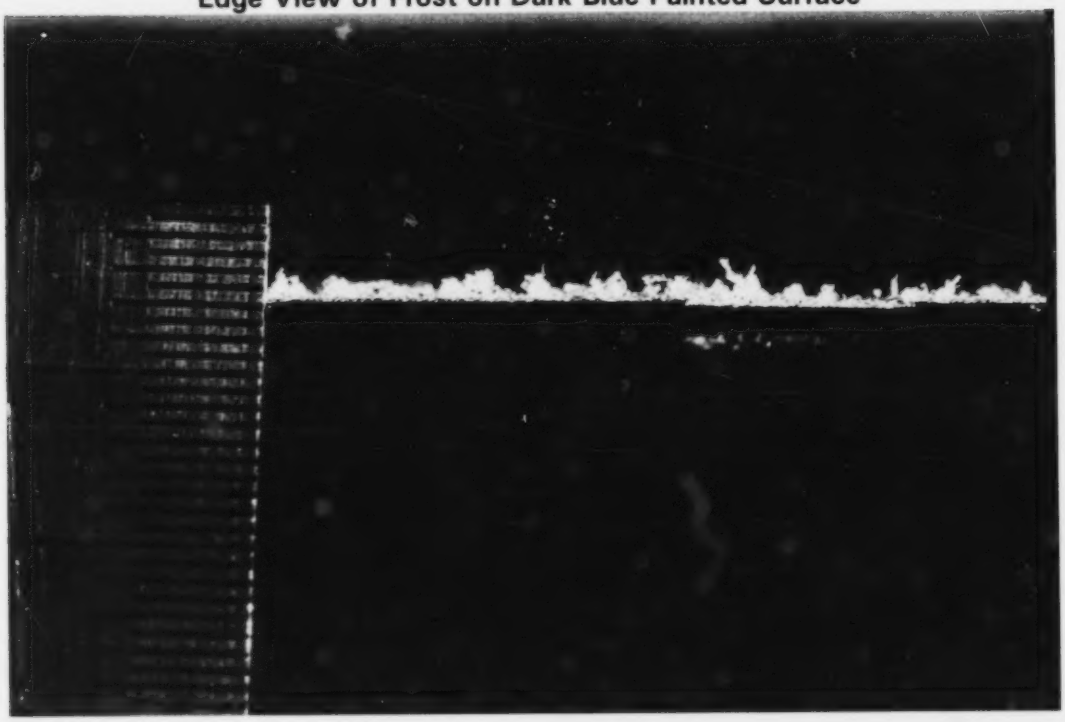


Photo 5.4
Painted Surface: Dark Blue and White

6. CONCLUSIONS

6.1 Natural Snow and Freezing Rain

The data shown and analysed in this report encompass six acquisition sites. Increasing the number of data collection sites increases the range of temperatures observed and provides a better interpretation of generalized weather conditions.

Few freezing rain data were detected from the weather station logs. The majority of the data on freezing rain were centred in the -3 to -5°C interval. The 95th percentile precipitation rate from the limited freezing rain data was approximately 25 g/dm^2/h.

Data analysis indicates that the current holdover time rate evaluation limits for snow are satisfactory. A high rate of snow precipitation in cold weather was observed during some of the snowstorms documented during the winter of 1998-99. High rates occur for short periods of time during snow precipitation, in all temperature ranges.

In the -14 to -25°C range, the 95th percentile was 22 g/dm^2/h. The subdivision of this temperature range indicated that precipitation rates below -18°C were significantly lower and occurrences were less frequent. Based on the data analysed for this study, the precipitation rate limits could be reduced if the coldest temperature range was between -18 and -25°C.

6.2 Evaluation of Fog Deposition Rates in Natural Snow

Only one fog deposition test was conducted during the 1999-2000 test season. In this case, the fog was reported as dense, with a maximum visibility of 500 feet. The obtained rate of 1.29 g/dm^2/h is slightly below the lower precipitation rate limit currently used in holdover time testing in simulated conditions.

6.3 Evaluation of Frost Deposition Rates in Natural Snow

From the results of the frost tests in Thompson, Manitoba, it is possible to conclude that:

- Frost rates measured ranged from 0 to 0.10 g/dm^2/h;
- The rate of frost deposition is surface-dependent;
- Frost does not readily accumulate on bare aluminum surfaces;

- Frost does accumulate on painted aluminum surfaces; and
- Composite surfaces and honeycomb-backed surfaces (similar to aircraft flight controls) are prone to frost accumulation.

In general, the rates obtained in natural conditions at the colder temperatures agree with the values observed in frost calibration trials at IREQ, which were approximately 0.03 g/dm^2/h at -25°C. The frost depositions obtained in trials at Thompson and IREQ at -25°C are below the rate proposed for use in Aerospace Standard 5485, which is 0.06 g/dm^2/h.

7. RECOMMENDATIONS

1. More data should be collected and analysed from the six weather stations in Quebec. Data, if available, from additional stations should be included to increase the range of temperatures observed. Stations located outside the province of Quebec could provide data from warmer and colder regions. Several reports were published on temperature relationships and the occurrence of precipitation. These reports should be evaluated in detail in the upcoming season.

2. The temperature ranges used to establish snow holdover times should be re-evaluated according to the weather data collected. Snow temperature ranges could be based on the frequency of precipitation in each range. Because the snow column is used 70 percent of the time, consideration should be given to dividing the snow columns into Light Snow, Moderate Snow, and Heavy Snow.

3. Consideration should be given to break out the temperature ranges in the Holdover Time table at different temperatures for all precipitation conditions.

4. More natural fog deposition rates should be collected to correlate with the 2 to 5 g/dm²/hr range being used in environmental chambers.

5. Holdover time tests in frost conditions should be conducted as part of the winter holdover time test program.

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APPENDIX A

WORK STATEMENT

PROJECT DESCRIPTION

APPENDIX A

PROJECT DESCRIPTION EXCERPT FROM TRANSPORTATION DEVELOPMENT CENTRE WORK STATEMENT

AIRCRAFT AND FLUID HOLDOVER TIME TESTS FOR WINTER 1999-2000 (December 1999)

5.1.5 EVALUATION OF WINTER WEATHER DATA

5.1.5.1 Snow Rates

The contractor shall collect and evaluate snow weather data (precipitation rate/temperature data) during the winter to ascertain the suitability of the data ranges used to date for the evaluation of holdover time limits.

In addition to Dorval (Montreal), The contractor shall obtain current data from Environment Canada for three sites in Quebec: Rouyn, Pointe-au-Père (Mont-Joli), and Ancienne Lorette (Quebec City).

5.1.5.2 Fog Deposition Rates

The contractor shall conduct fog deposition measurements outdoors, using a procedure devised during the past year, on at least two occasions to determine the range of fog deposition rates that occur in natural conditions.

5.1.5.3 Frost Deposition Rates

Frost deposition rates have been collected in natural conditions at Dorval Airport over the past two years in order to determine a deposition range for this condition. The contractor shall attempt to collect deposition rates in cold temperatures (for example in Thompson, Manitoba). A total of three sessions are proposed.

APPENDIX B

WINTER WEATHER DATA 1995 to 2000

APPENDIX B

WINTER WEATHER DATA

1995 TO 2000

The following charts include the complete rate data analysis, subdivided by temperature ranges for both snow and freezing rain. A histogram of points and a cumulative probability chart are included for each rate calculation interval in all temperature ranges.

The lowest holdover time temperature range for snow conditions was subdivided into three ranges. The charts for this analysis are also included.

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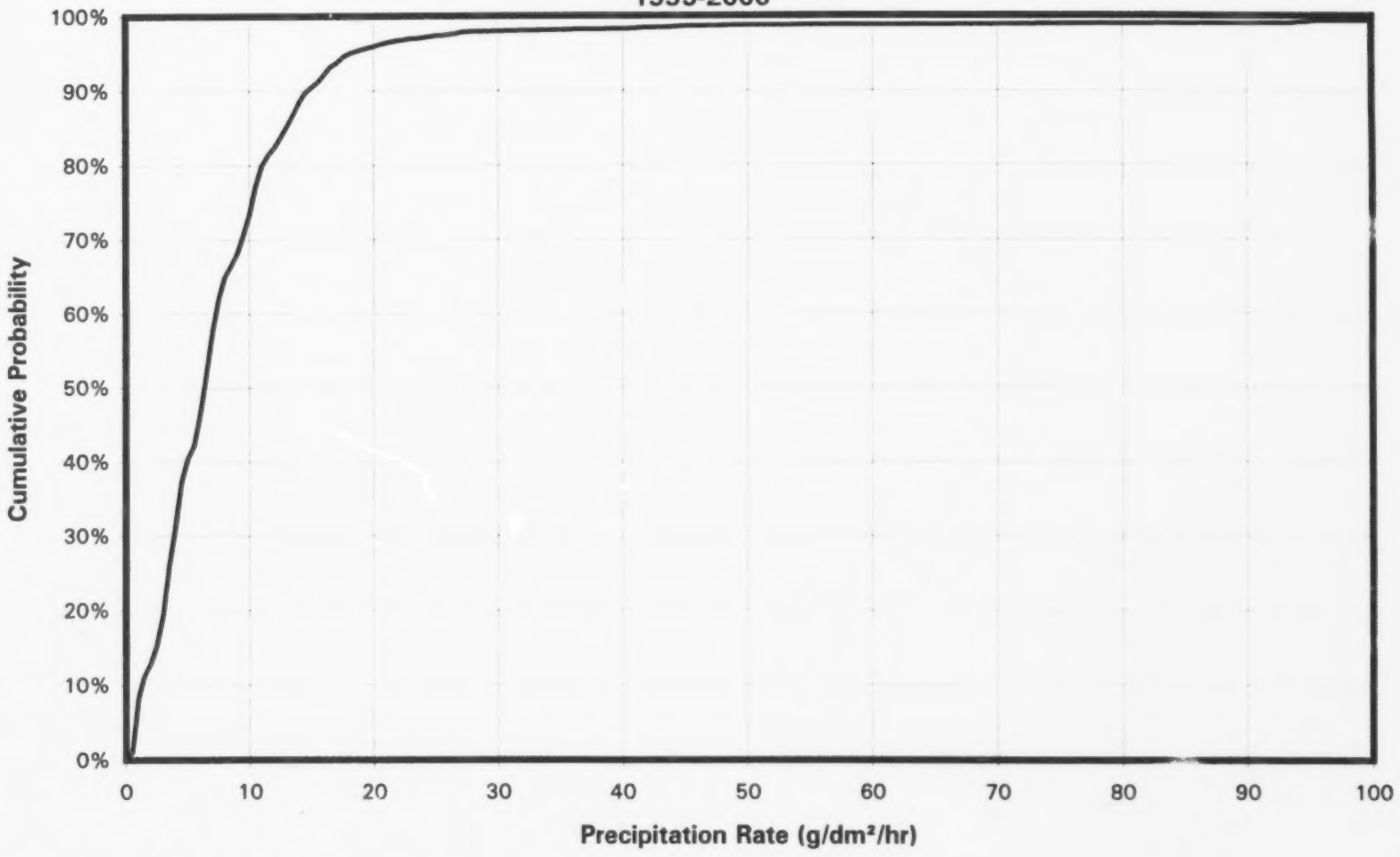
-22 to -25°C, 20-minute rates B-58
-22 to -25°C, 6-minute rates B-60

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

35-MINUTE RATE EVERY MINUTE

1995-2000



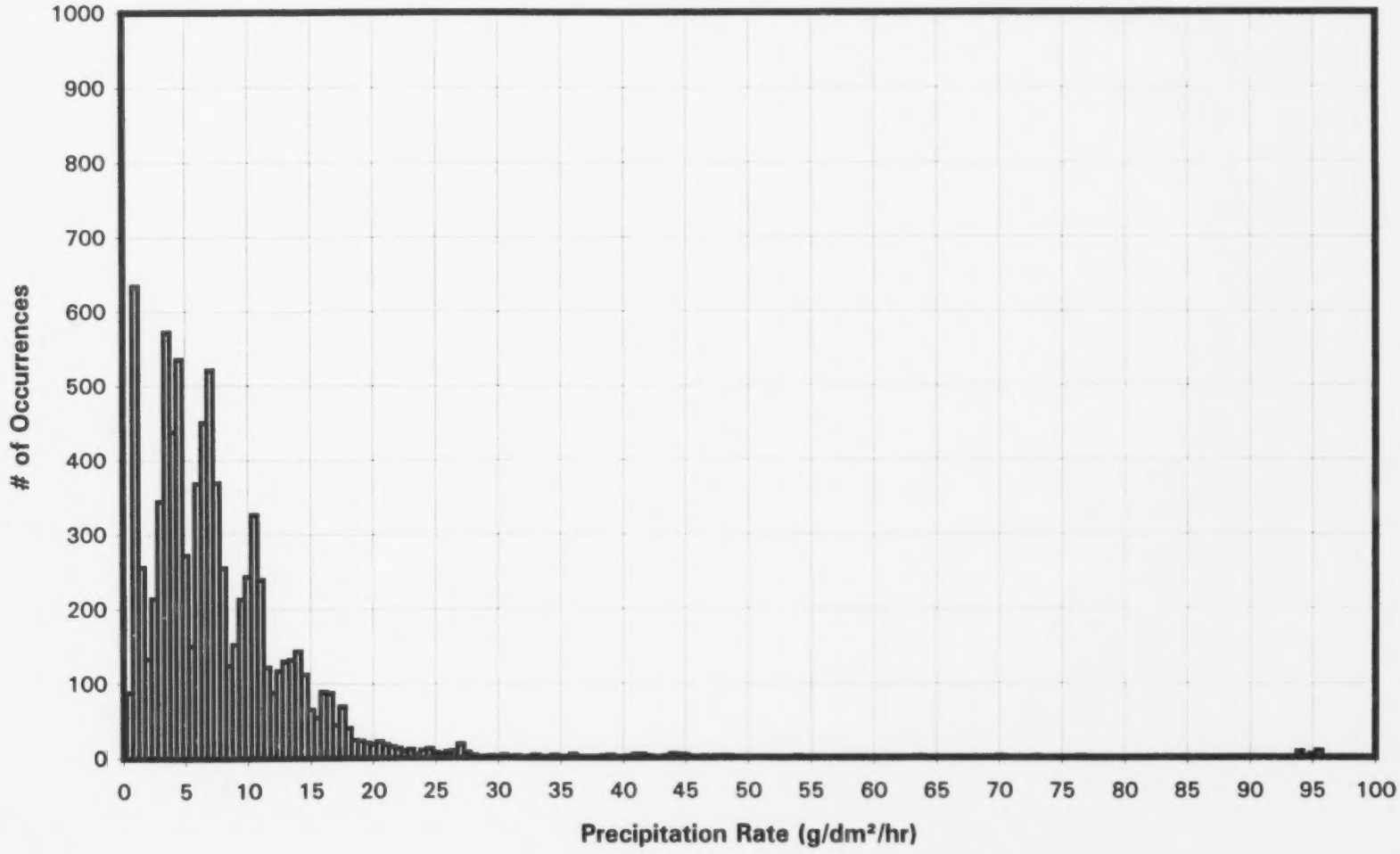
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At 35 min Cuml.
11/09/00 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

35-MINUTE RATE EVERY MINUTE

1995-2000



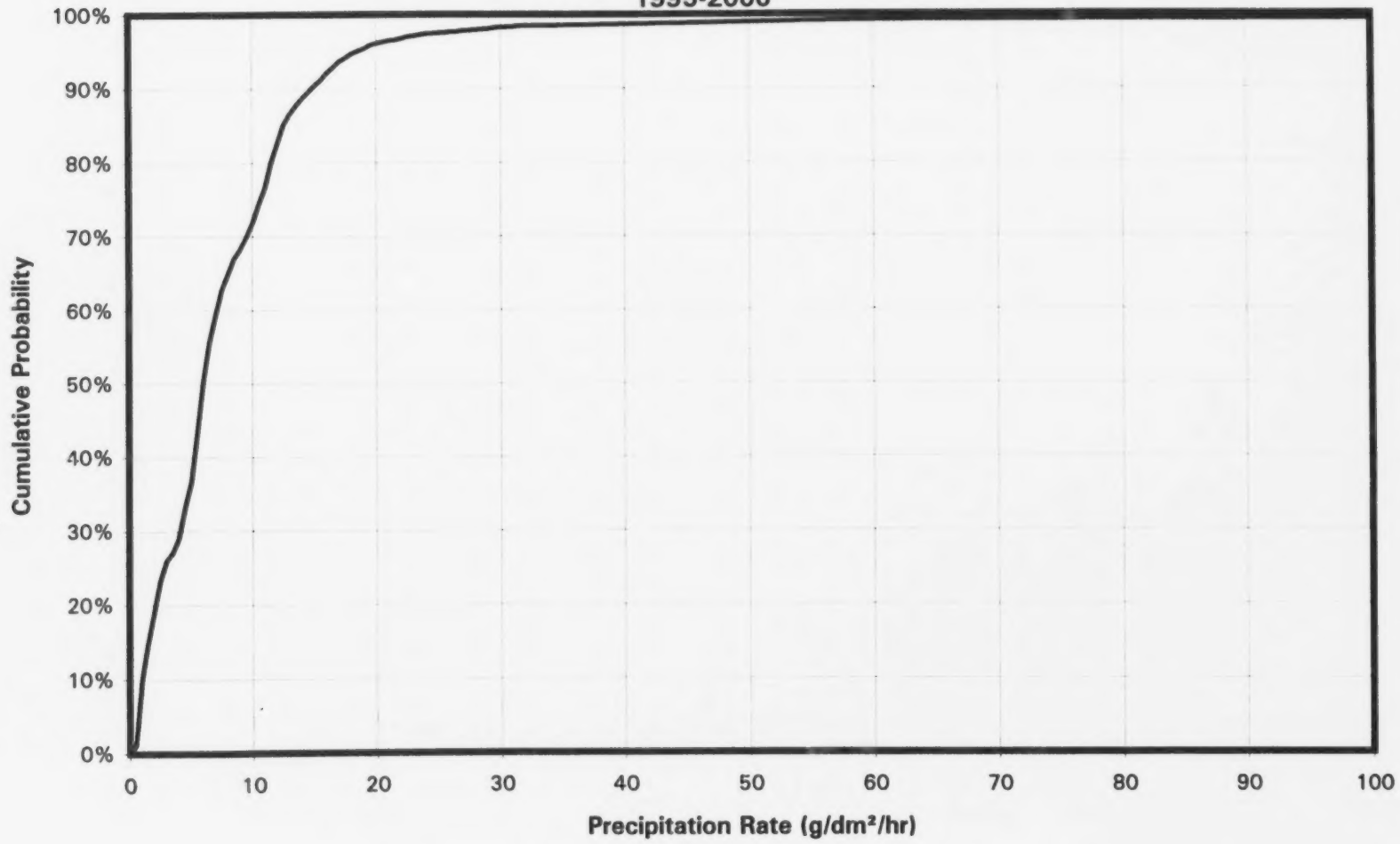
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At: 35 min Hist
11/09/00, 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

20-MINUTE RATE EVERY MINUTE

1995-2000



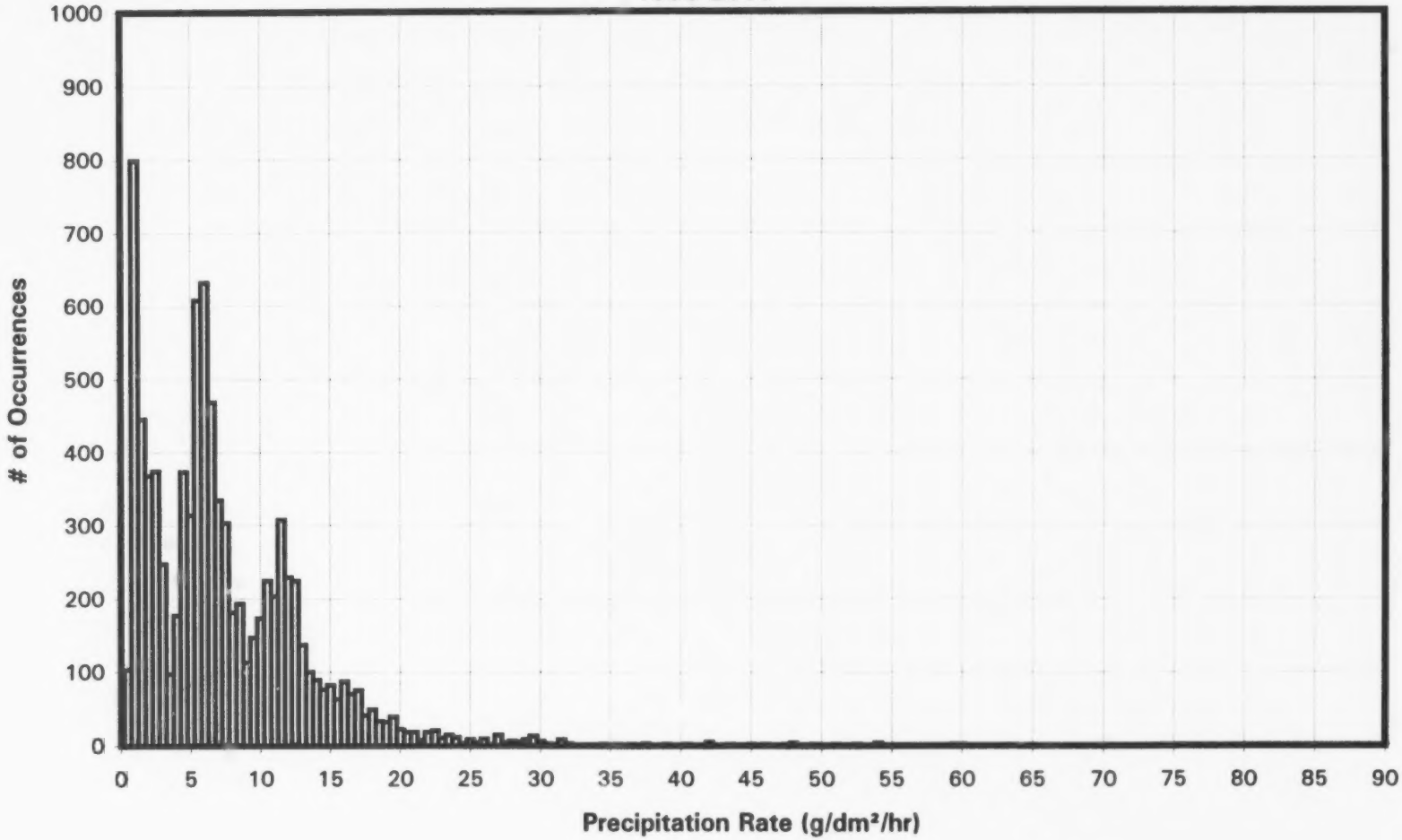
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At: 20 min Cuml.
11/09/00, 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

20-MINUTE RATE EVERY MINUTE

1995-2000



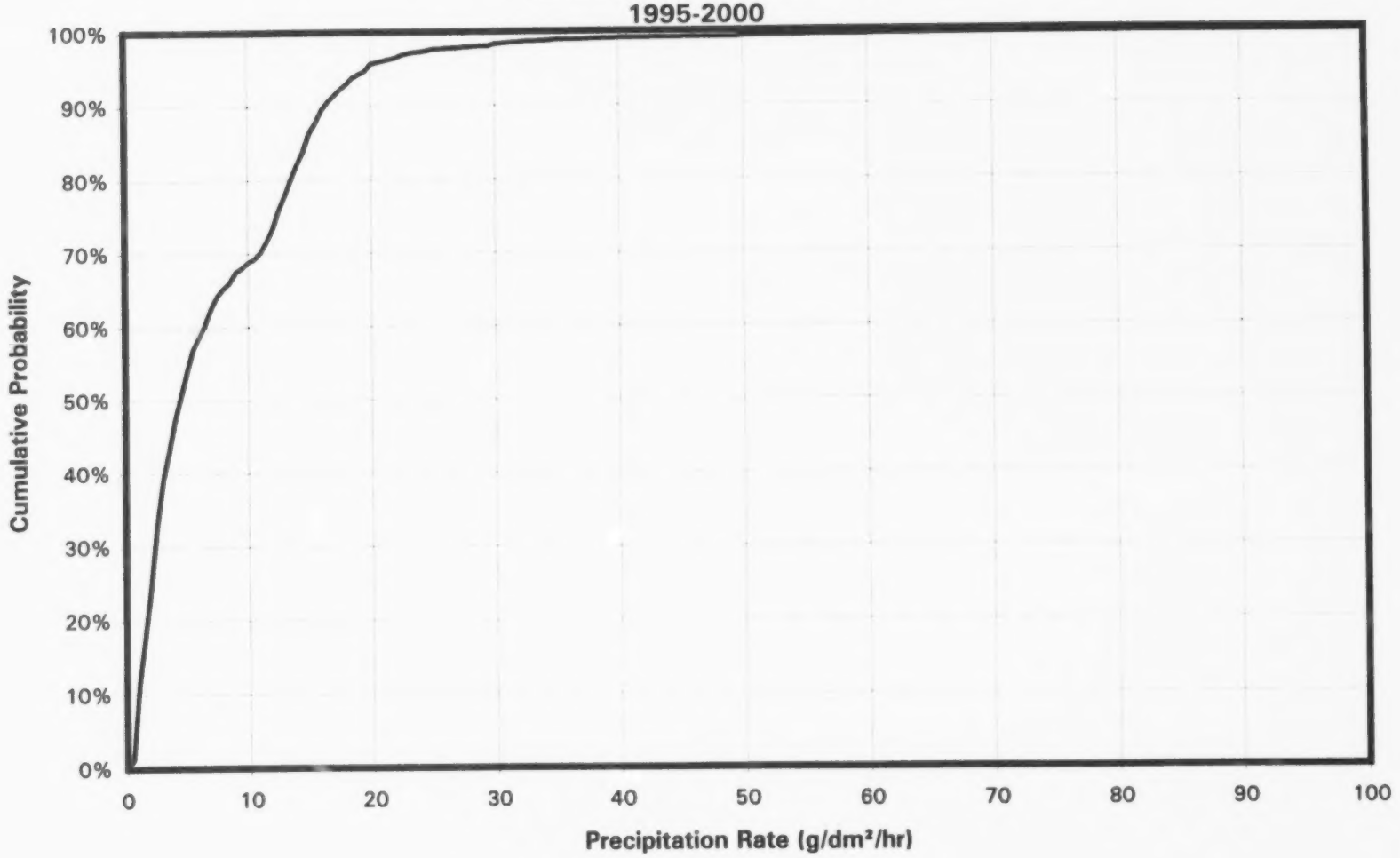
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At: 20 min Hist
11/09/00, 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

6-MINUTE RATE EVERY MINUTE

1995-2000



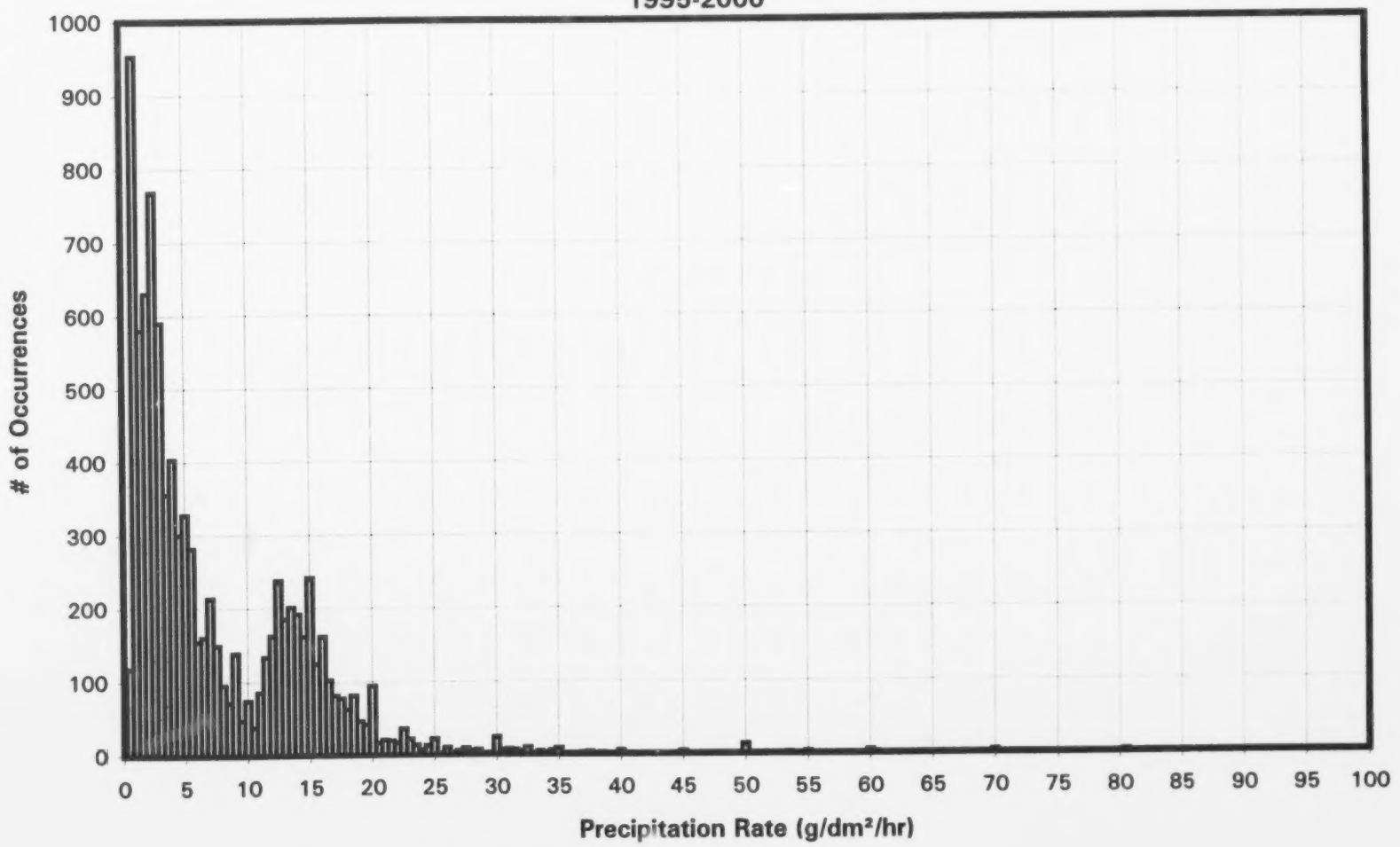
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At: 6 min Cuml.
11/09/00, 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

ABOVE 0°C

6-MINUTE RATE EVERY MINUTE

1995-2000



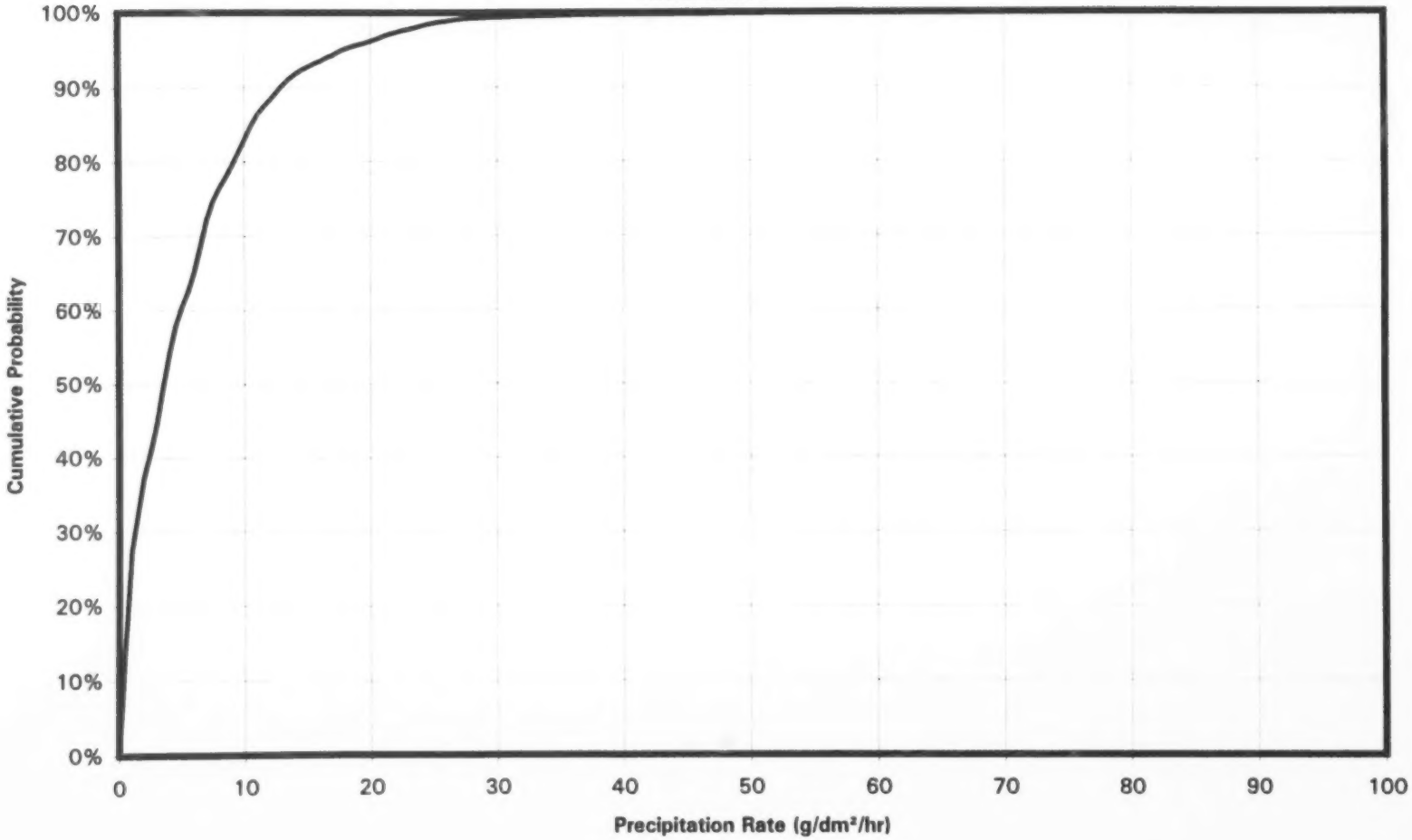
cm1589/analysis/readac/Snow Analysis (Above 0°C)
At: 6 min Hist
11/09/00, 8:17 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

35-MINUTE RATE EVERY MINUTE

1995-2000



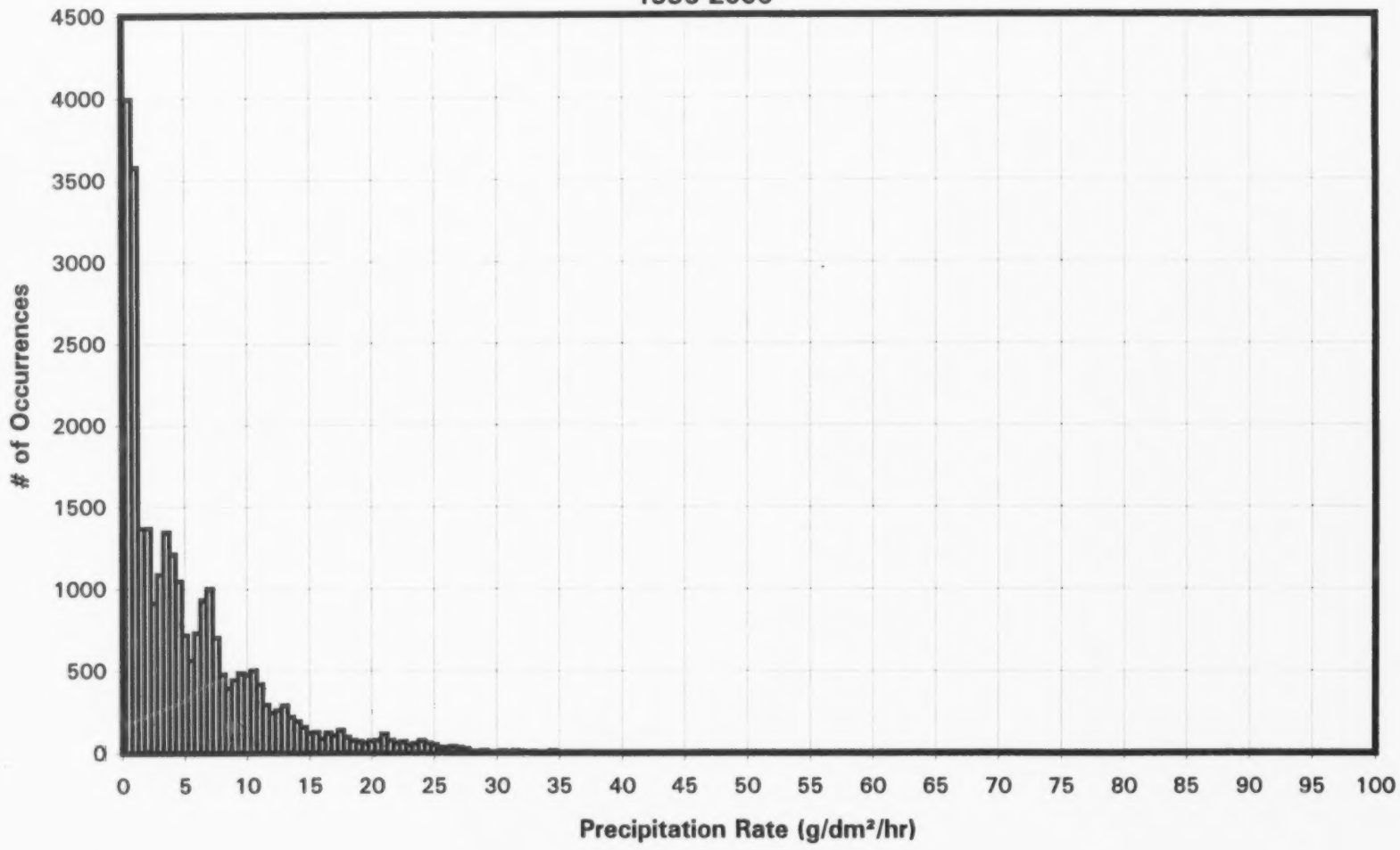
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 35 min Cuml.
11/09/00, 8:18 AM

READADAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

35-MINUTE RATE EVERY MINUTE

1995-2000



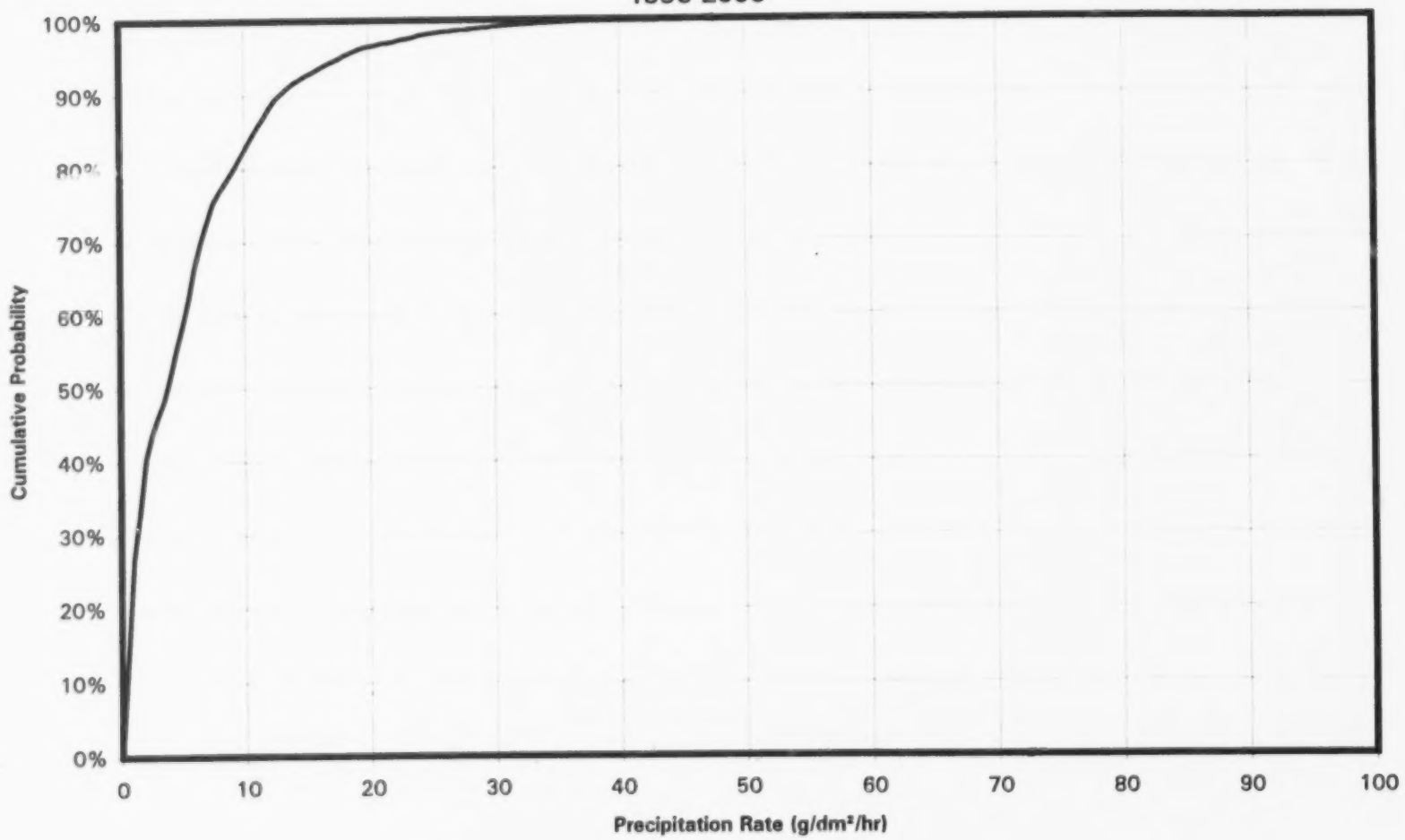
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 35 min Hist
11/09/00, 8:18 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

20-MINUTE RATE EVERY MINUTE

1995-2000



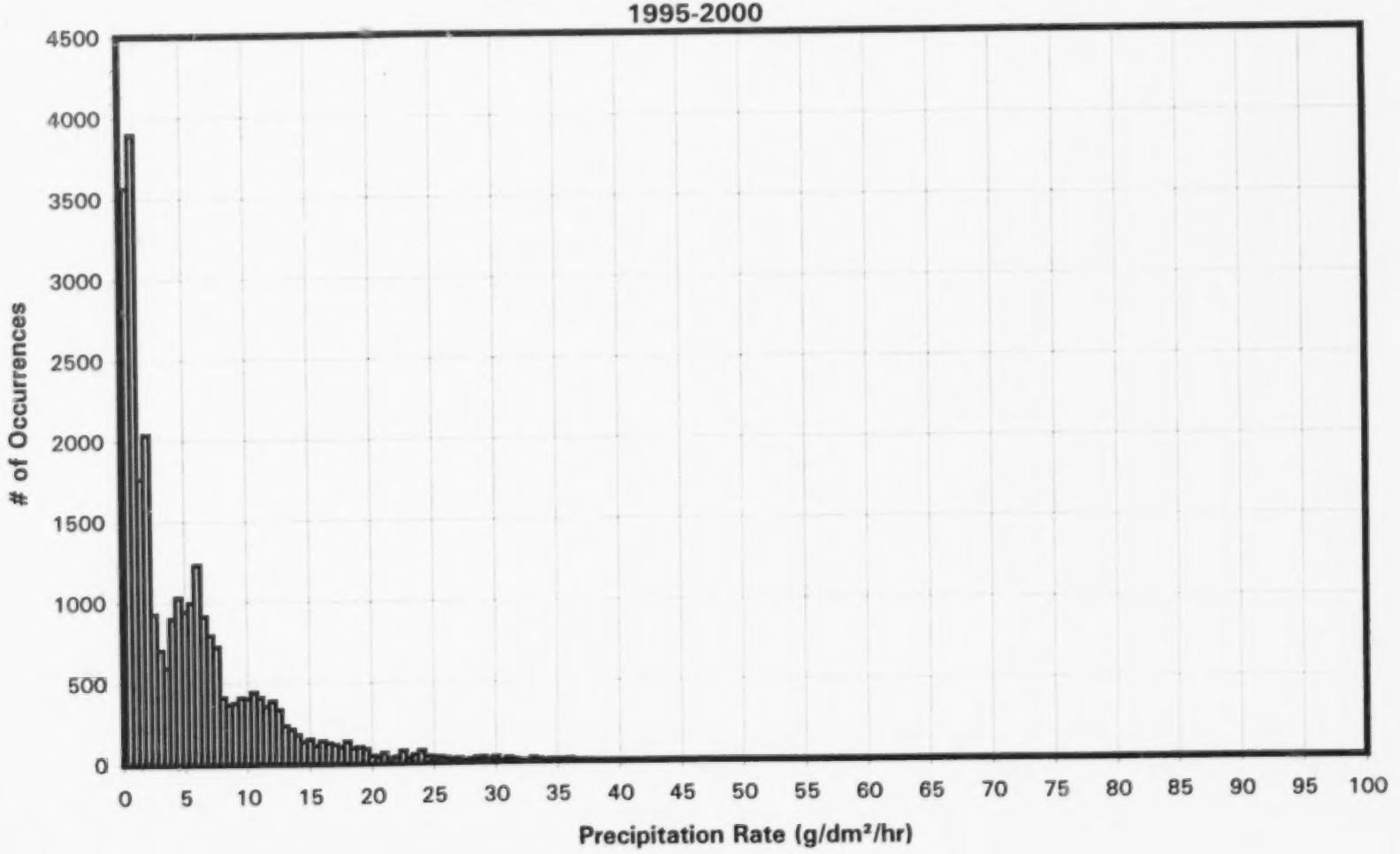
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 20 min Cuml.
11/09/00, 8:18 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

20-MINUTE RATE EVERY MINUTE

1995-2000



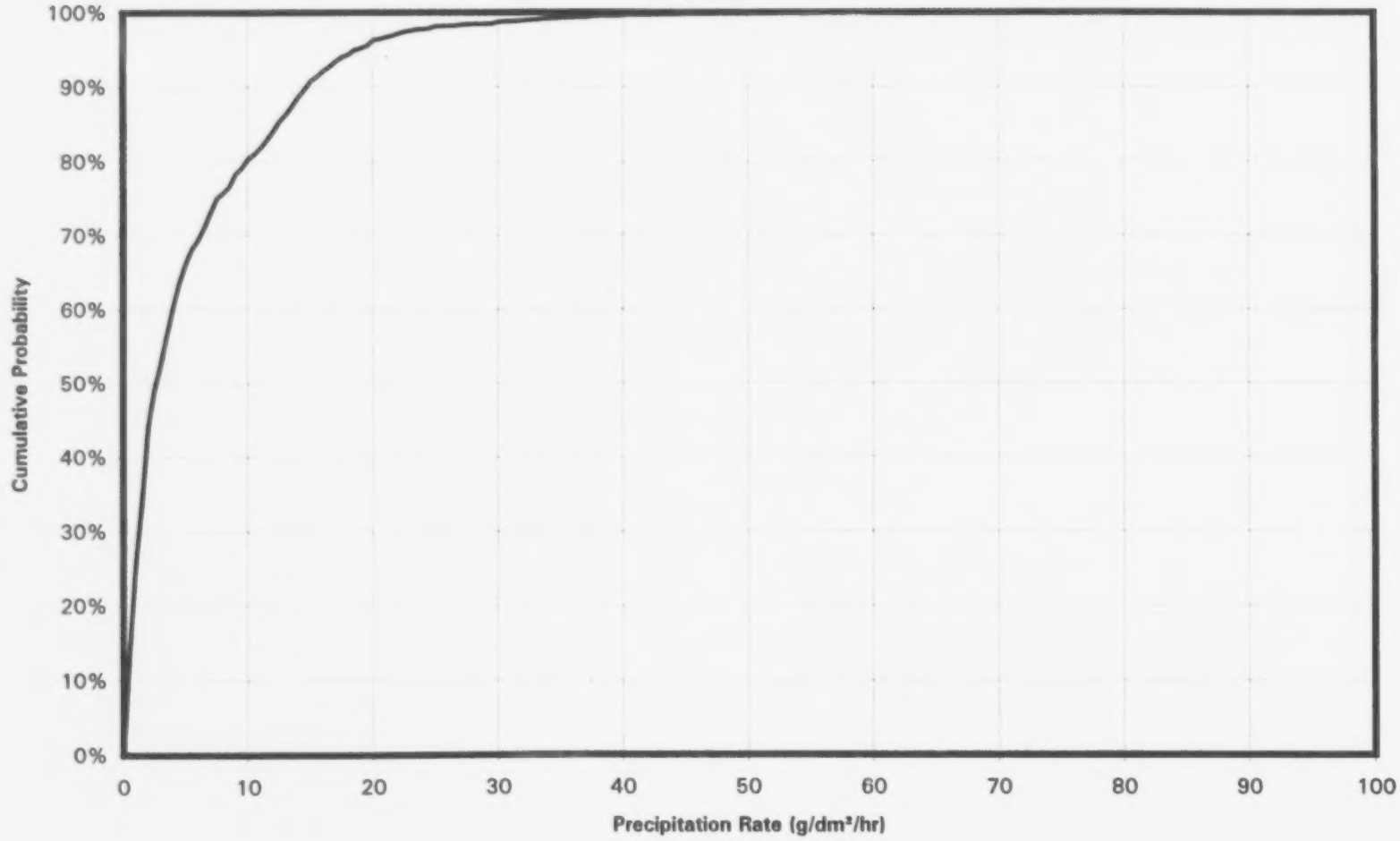
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 20 min Hist
11/09/00, 8:18 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

6-MINUTE RATE EVERY MINUTE

1995-2000



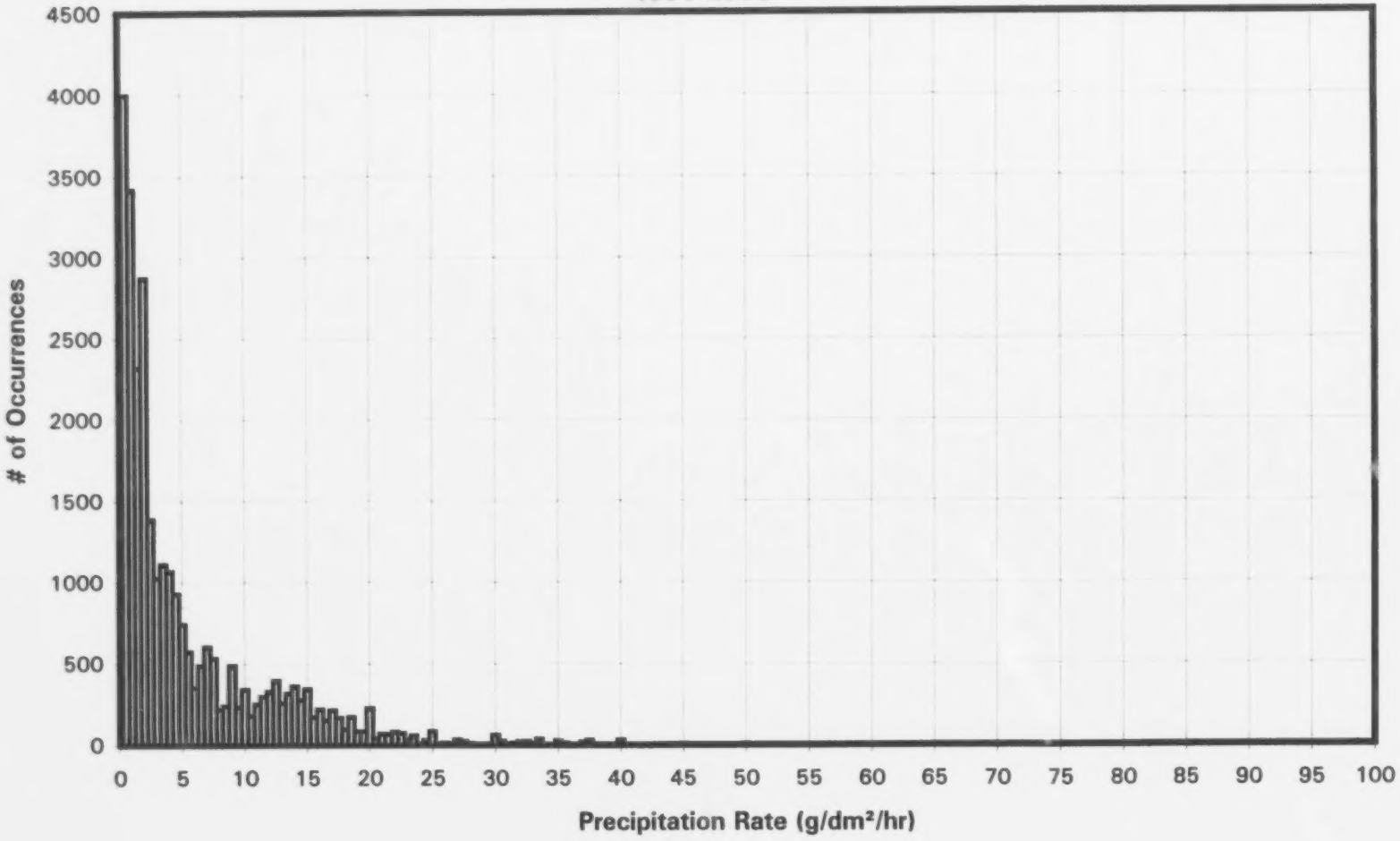
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 6 min Cuml.
11/09/00, 8:18 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

0 TO -3°C

6-MINUTE RATE EVERY MINUTE

1995-2000



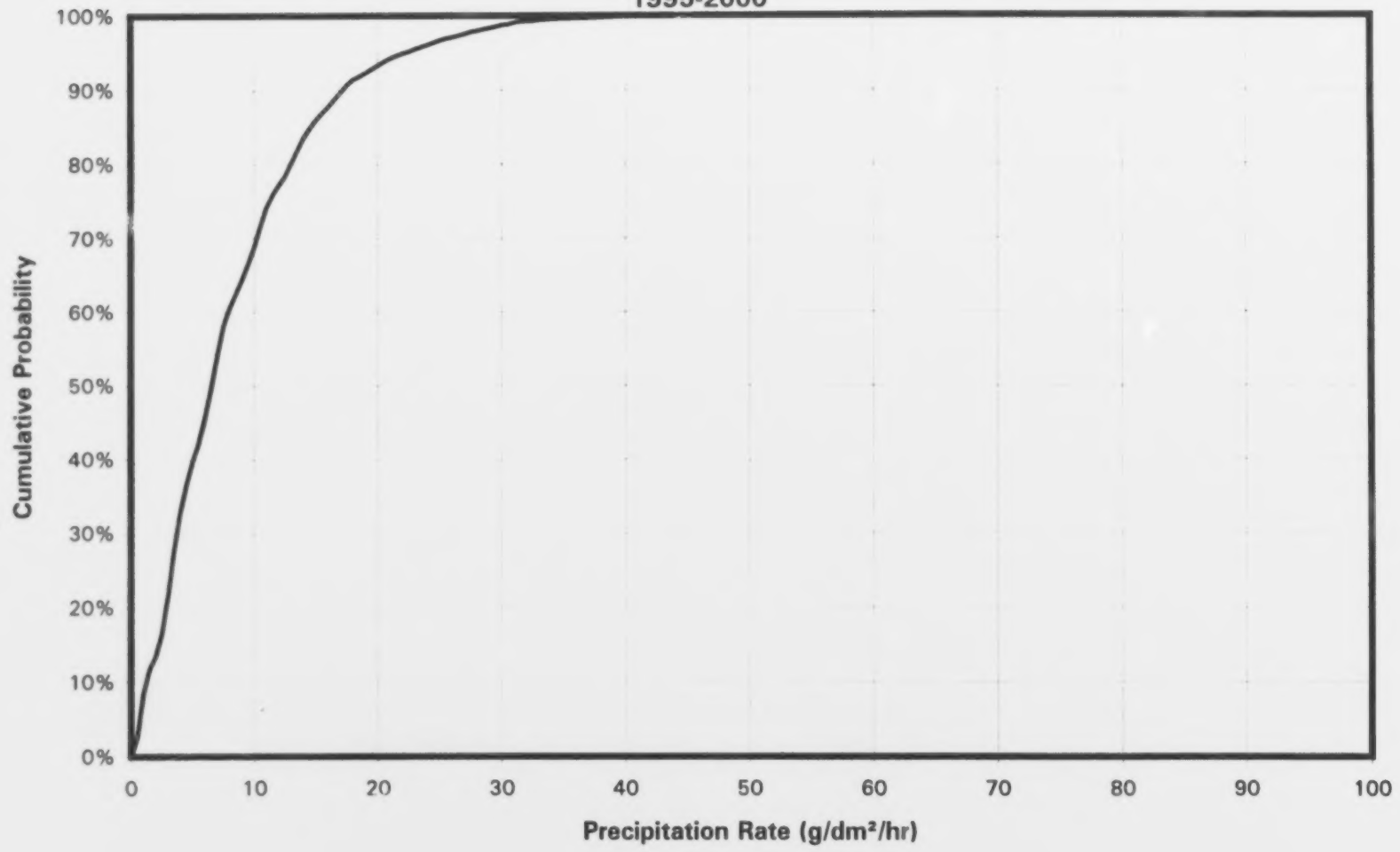
cm1589/analysis/readac/Snow Analysis (0 to -3°C)
At: 6 min Hist
11/09/00, 8:18 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 to -7°C

35-MINUTE RATE EVERY MINUTE

1995-2000



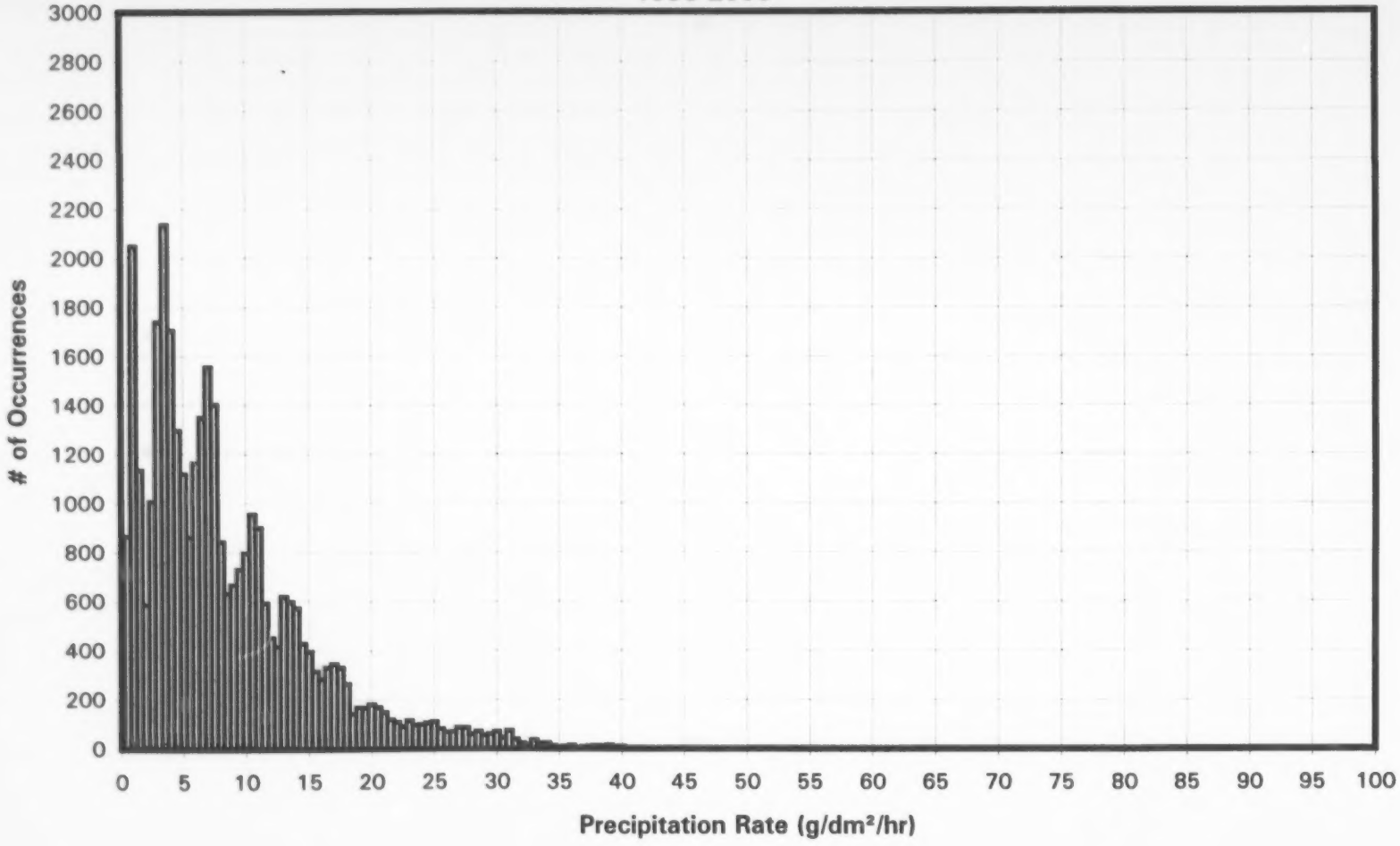
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 35 min Cuml.
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 TO -7°C

35-MINUTE RATE EVERY MINUTE

1995-2000



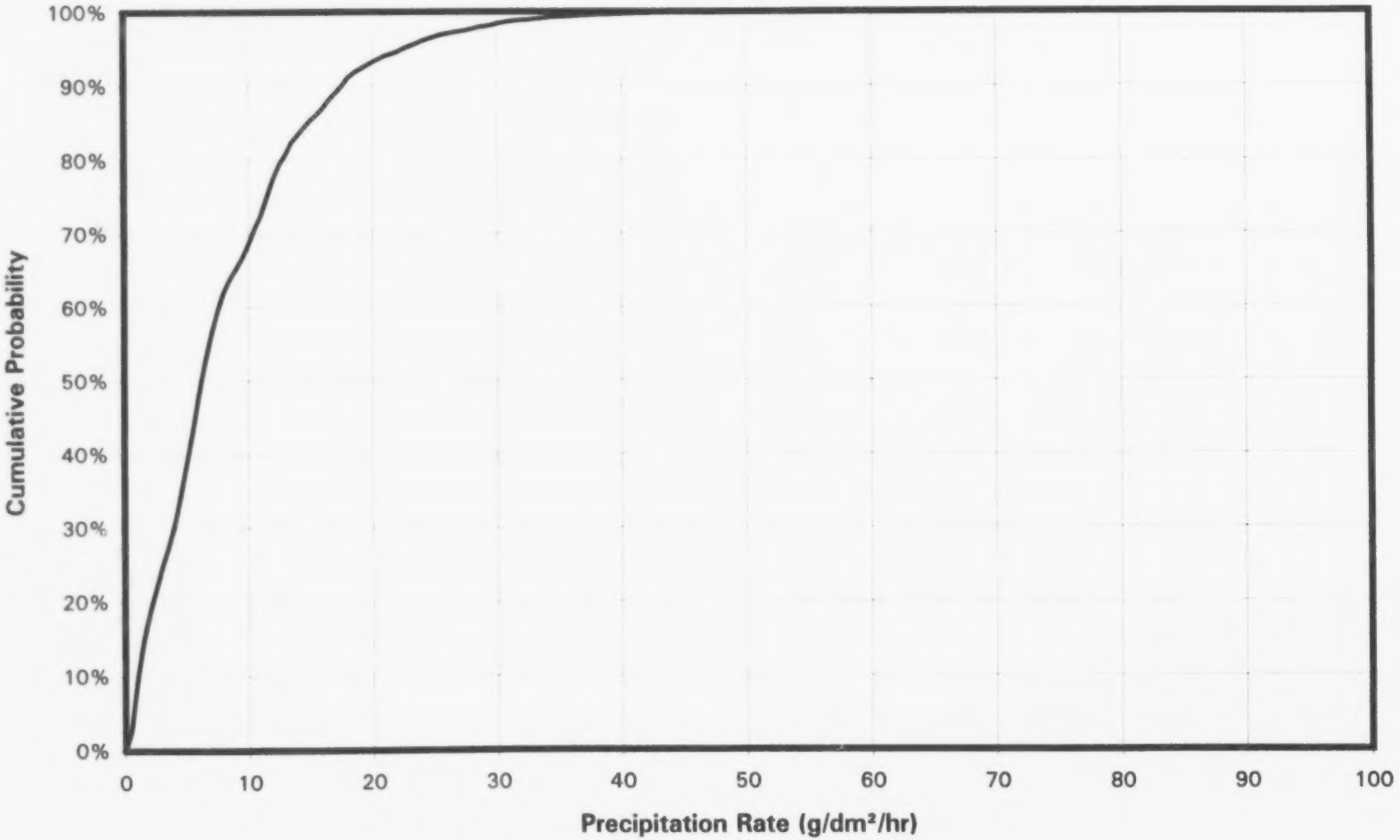
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 35 min Hist
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 TO -7°C

20-MINUTE RATE EVERY MINUTE

1995-2000



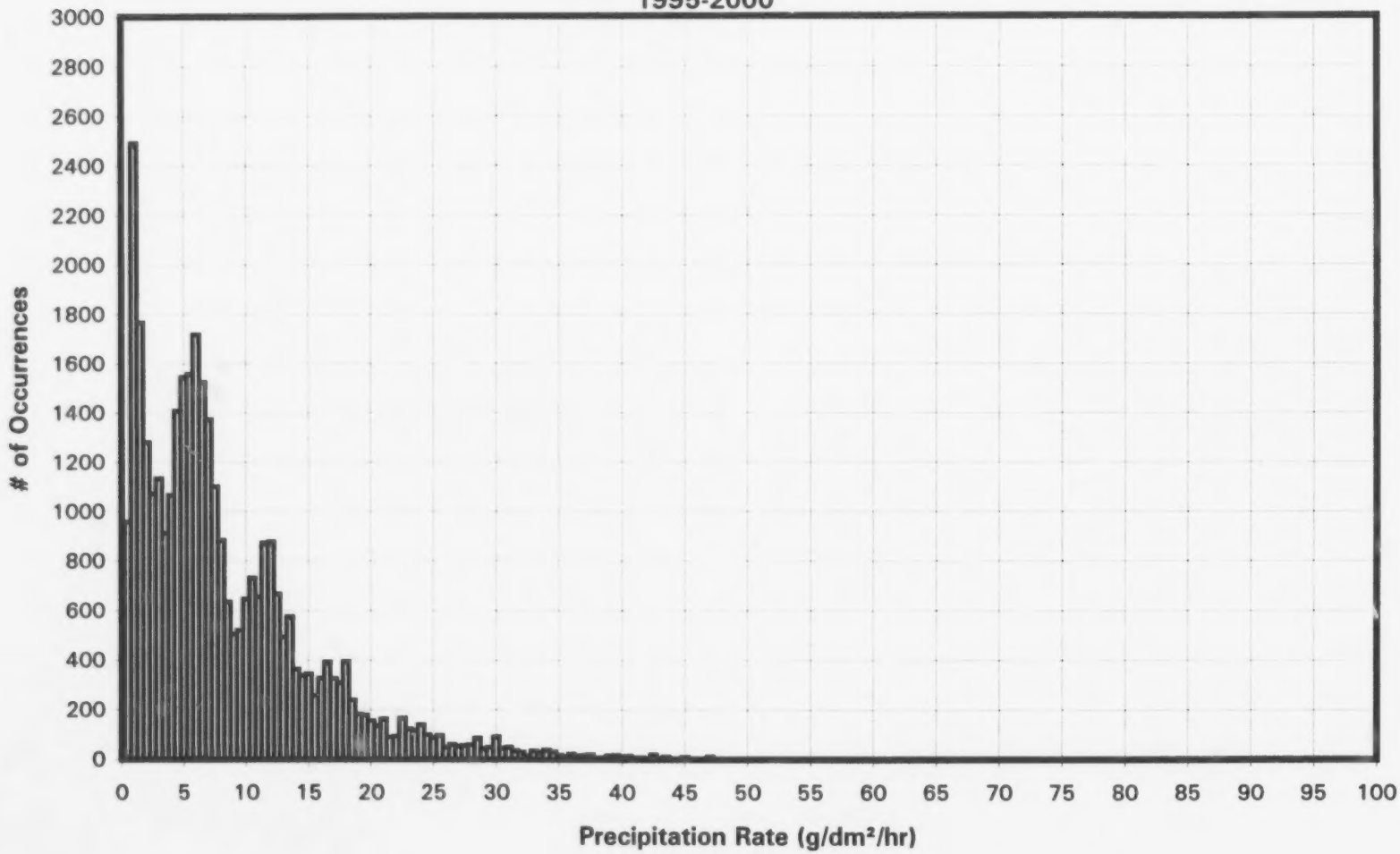
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 20 min Cuml.
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 TO -7°C

20-MINUTE RATE EVERY MINUTE

1995-2000



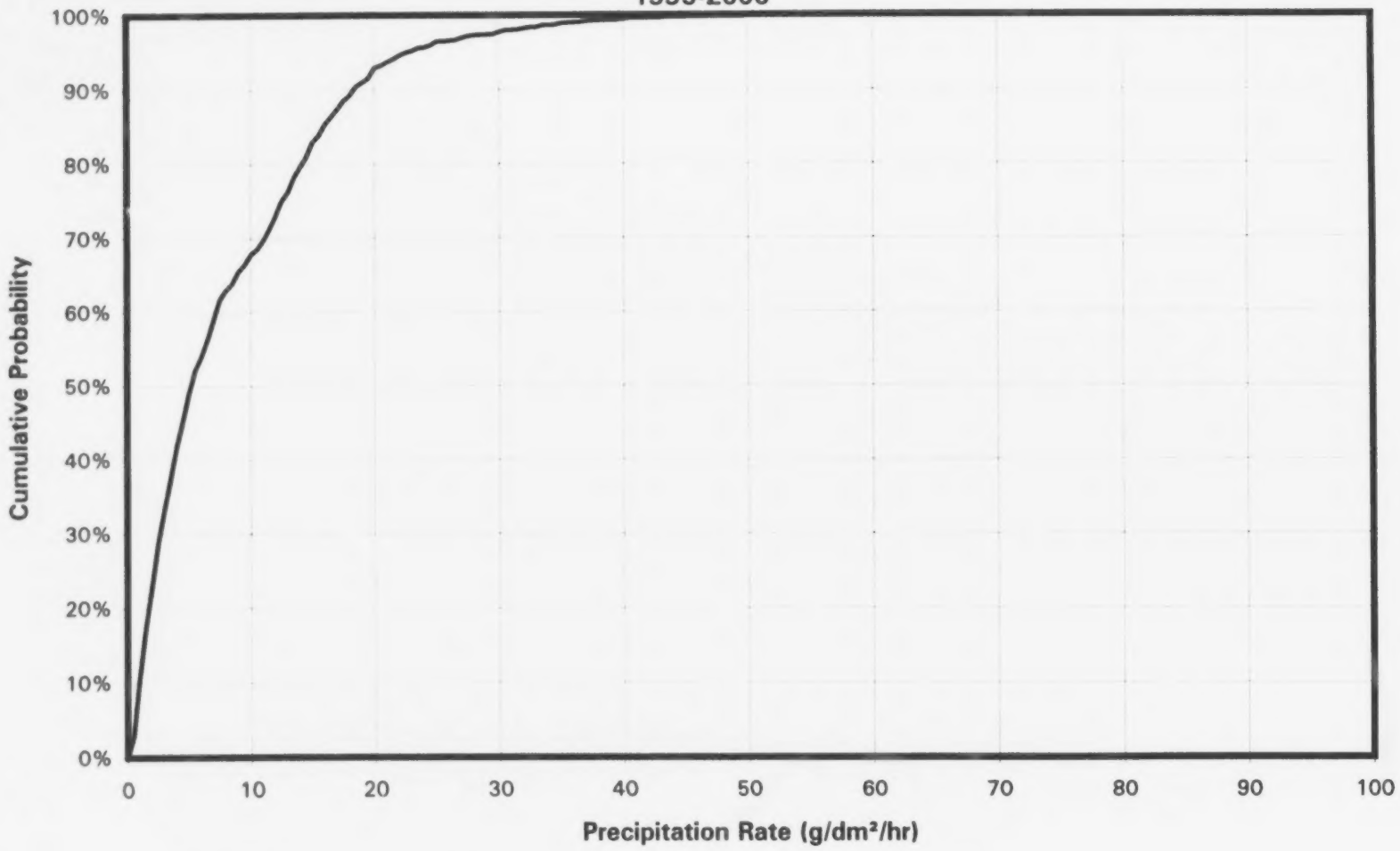
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 20 min Hist
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 TO -7°C

6-MINUTE RATE EVERY MINUTE

1995-2000



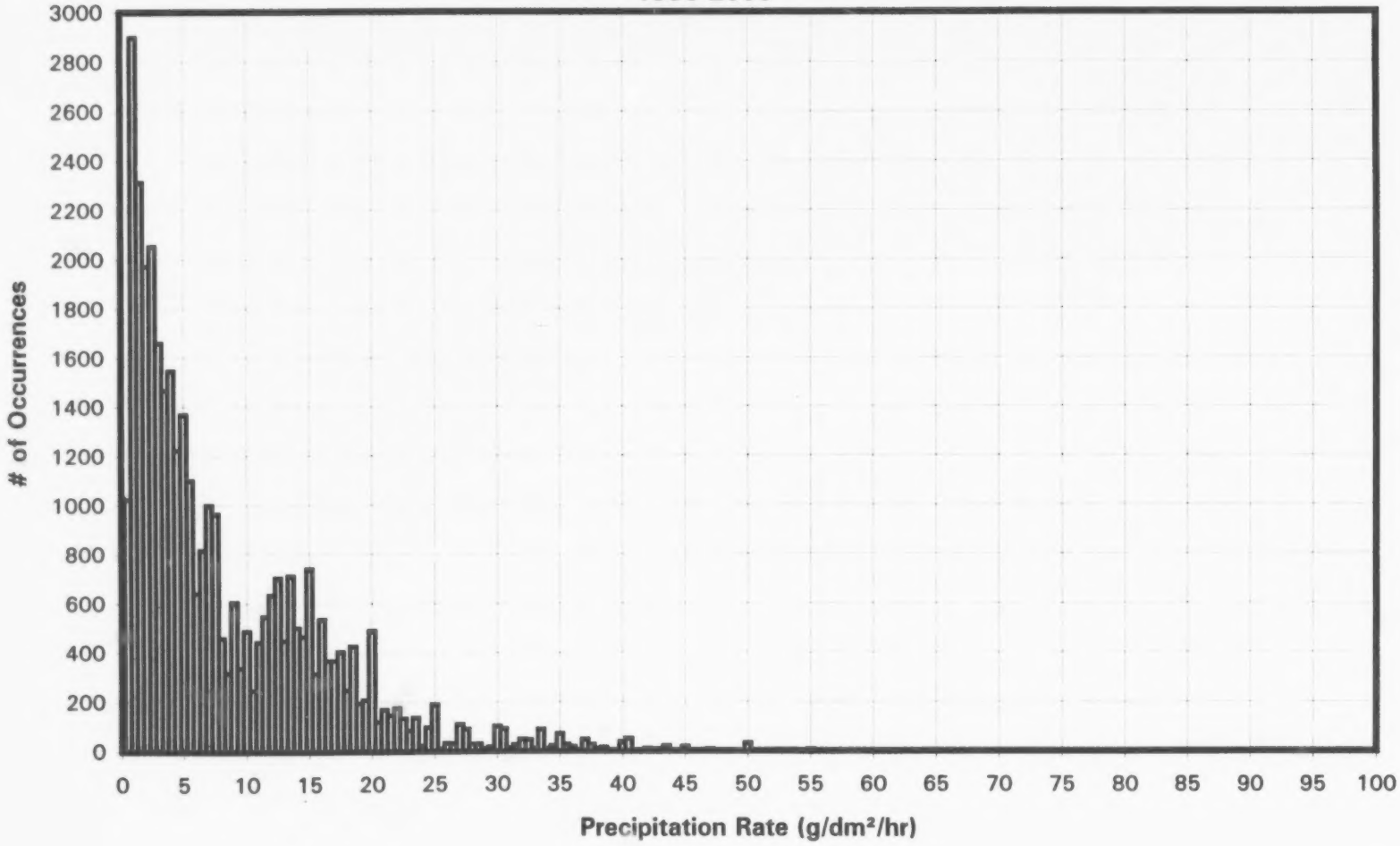
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 6 min Cuml.
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-3 TO -7°C

6-MINUTE RATE EVERY MINUTE

1995-2000



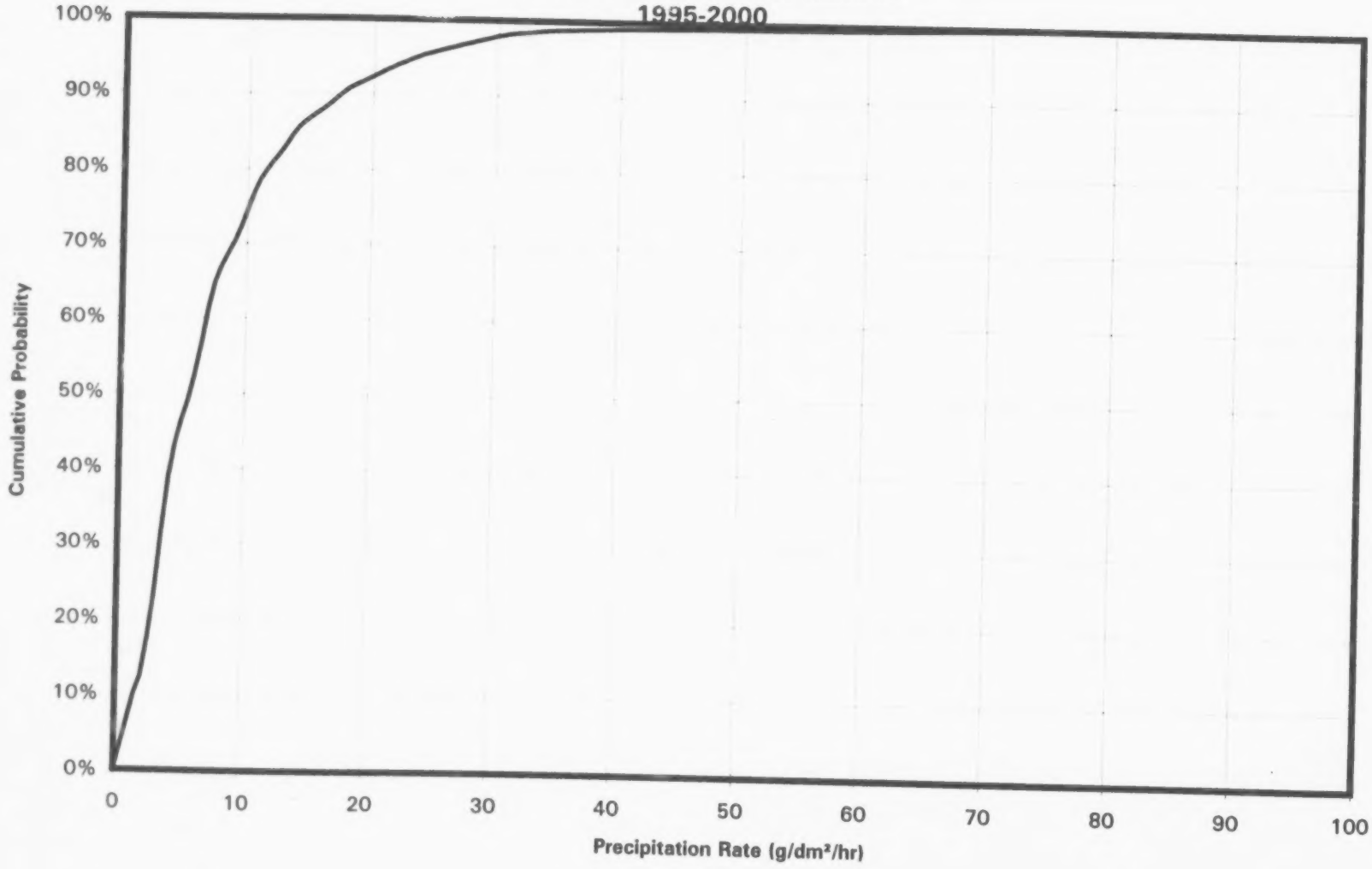
cm1589/analysis/readac/Snow Analysis (-3 to -7°C)
At: 6 min Hist
11/09/00, 8:22 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

35-MINUTE RATE EVERY MINUTE

1995-2000



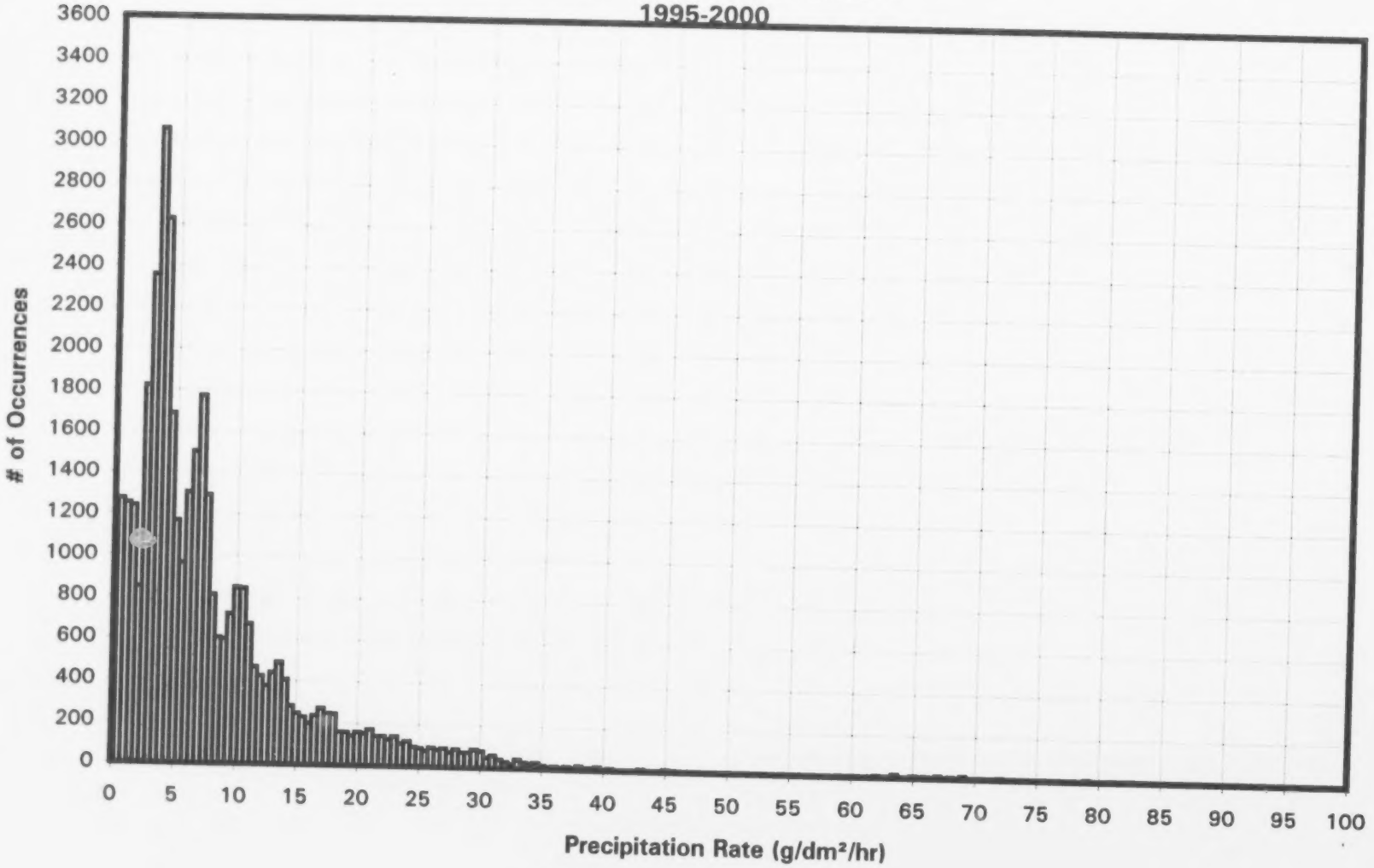
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 35 min Cuml.
11/09/00, 8:32 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

35-MINUTE RATE EVERY MINUTE

1995-2000



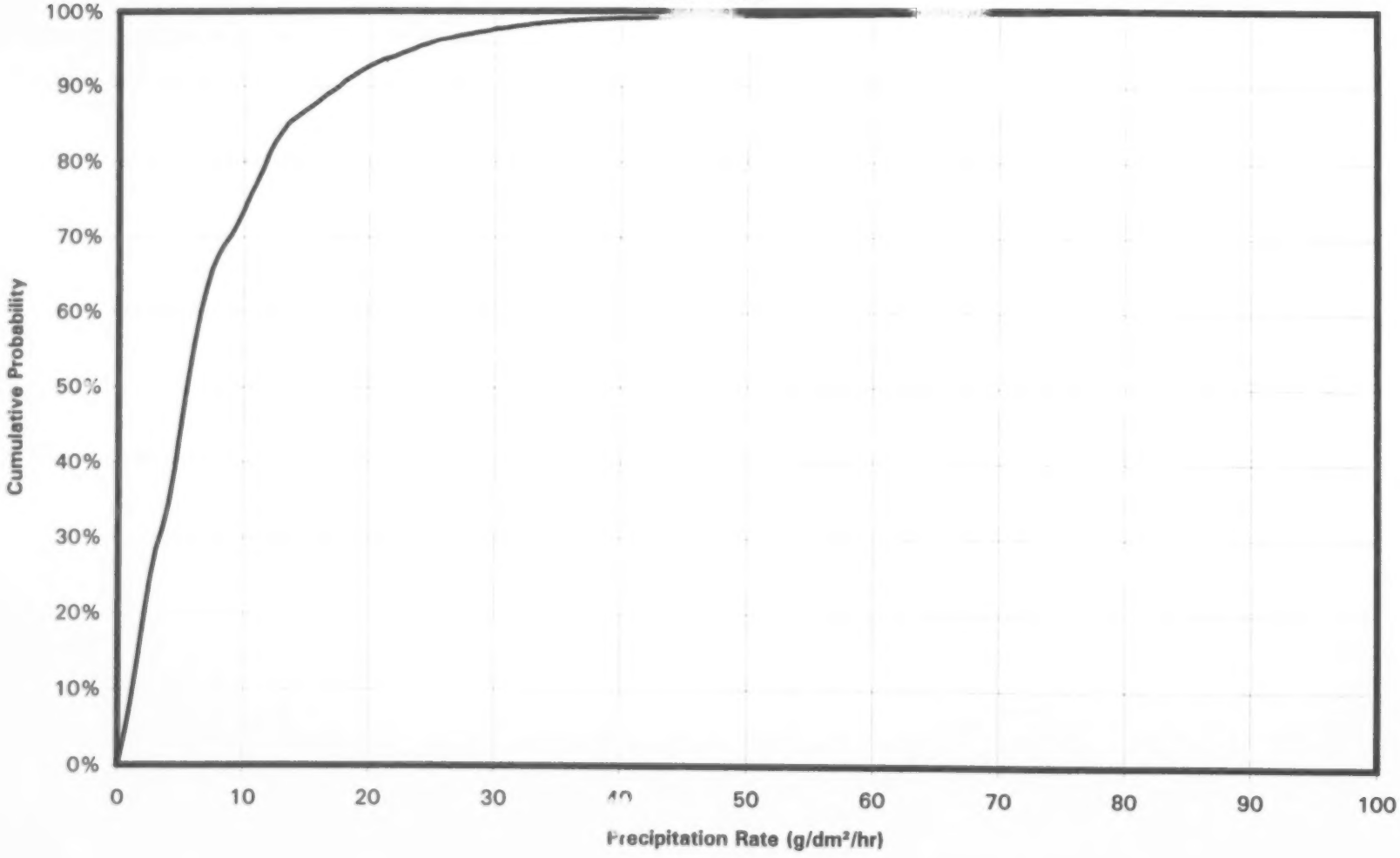
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 35 min Hist
11/09/00, 8:32 AM

READADAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

20-MINUTE RATE EVERY MINUTE

1995-2000



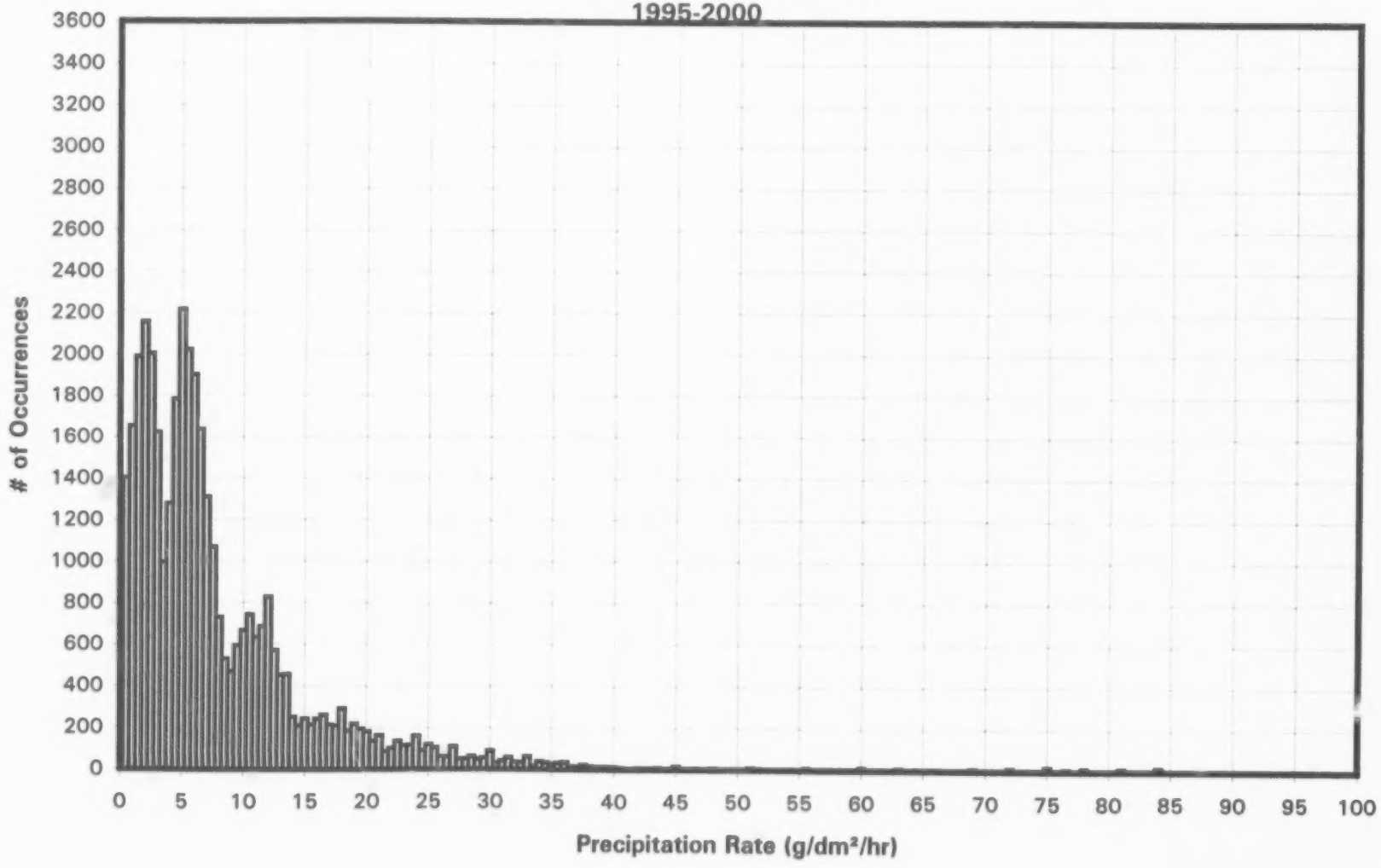
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 20 min Cuml.
11/09/00, 8:32 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

20-MINUTE RATE EVERY MINUTE

1995-2000



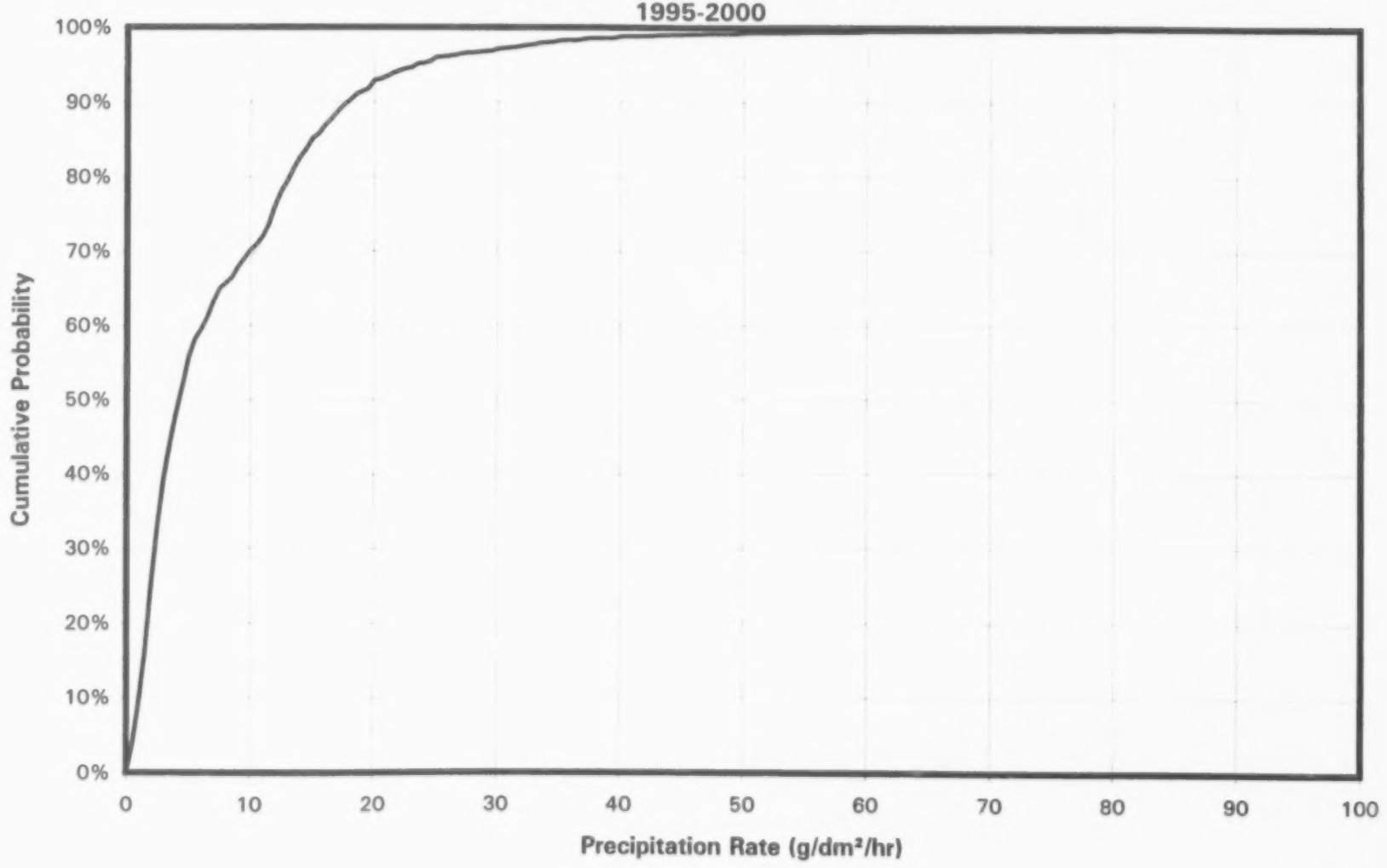
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 20 min Hist
11/09/00, 8:32 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

6-MINUTE RATE EVERY MINUTE

1995-2000



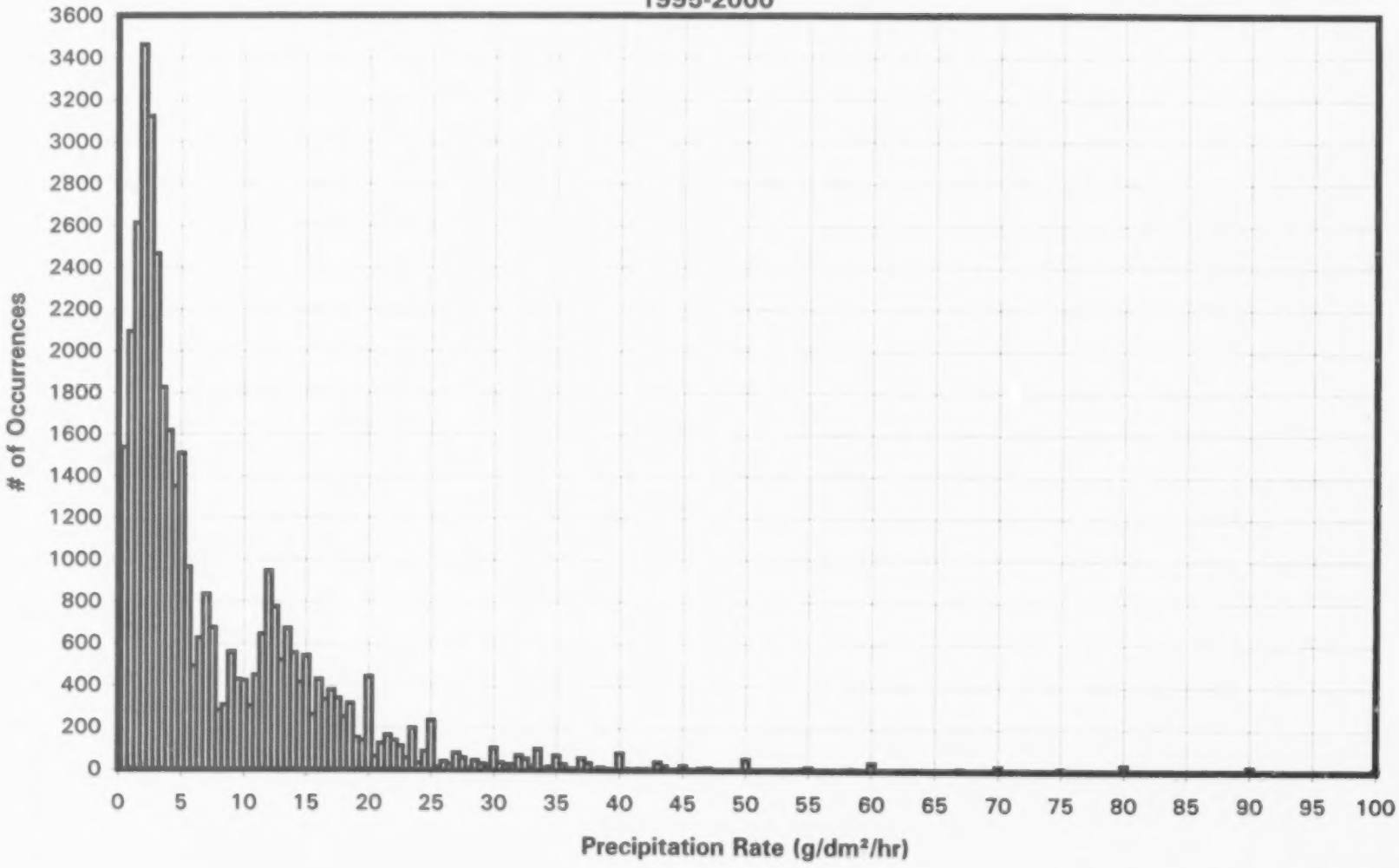
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 6 min Cuml.
11/09/00, 8:32 AM

READADAC AND CR21X ANALYSIS - NATURAL SNOW

-7 TO -14°C

6-MINUTE RATE EVERY MINUTE

1995-2000



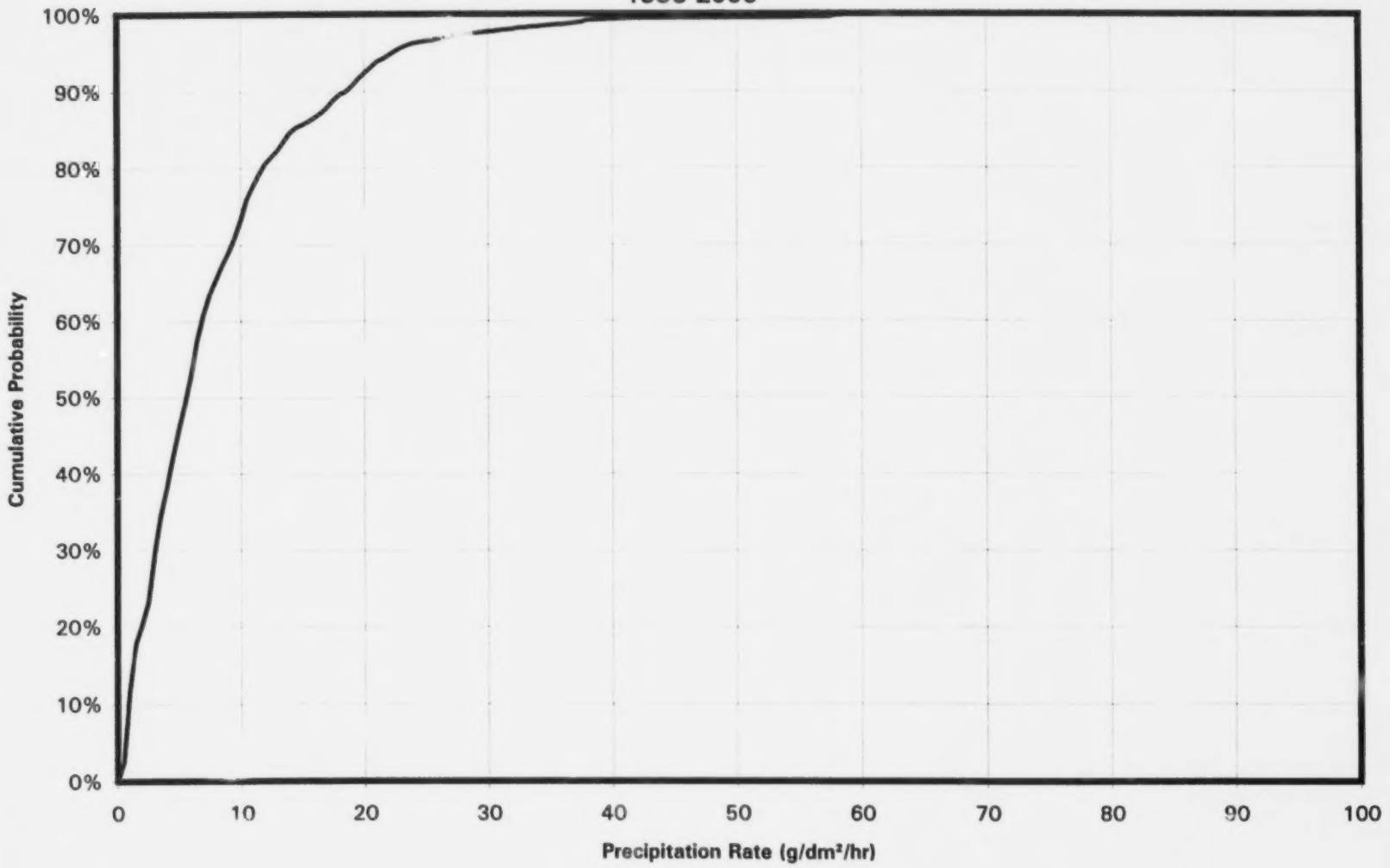
cm1589/analysis/readac/Snow Analysis (-7 to -14°C)
At: 6 min Hist
11/09/00, 8:32 AM

READADC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

35-MINUTE RATE EVERY MINUTE

1995-2000



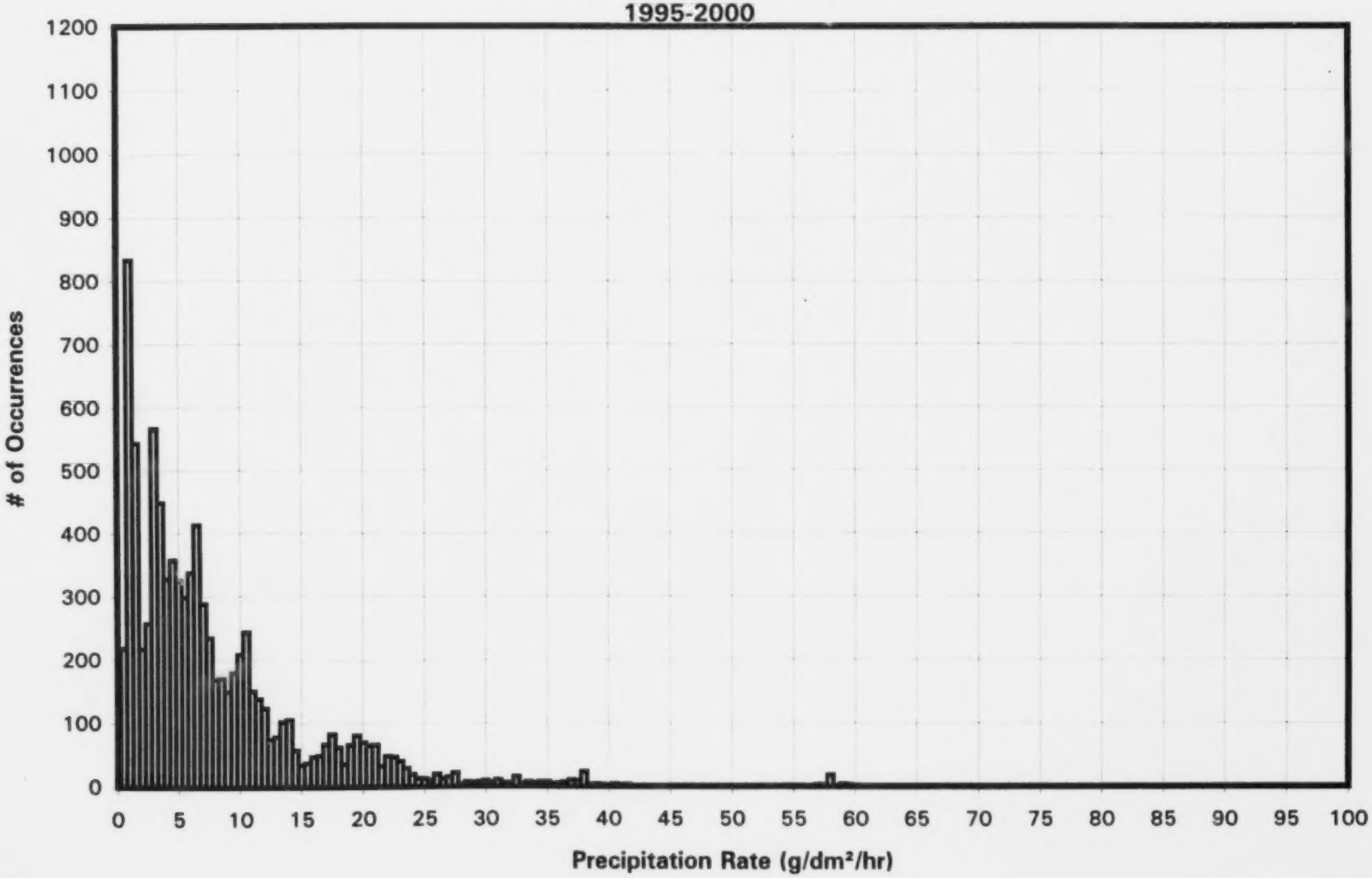
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 35 min Cuml.
11/09/00, 8:21 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

35-MINUTE RATE EVERY MINUTE

1995-2000



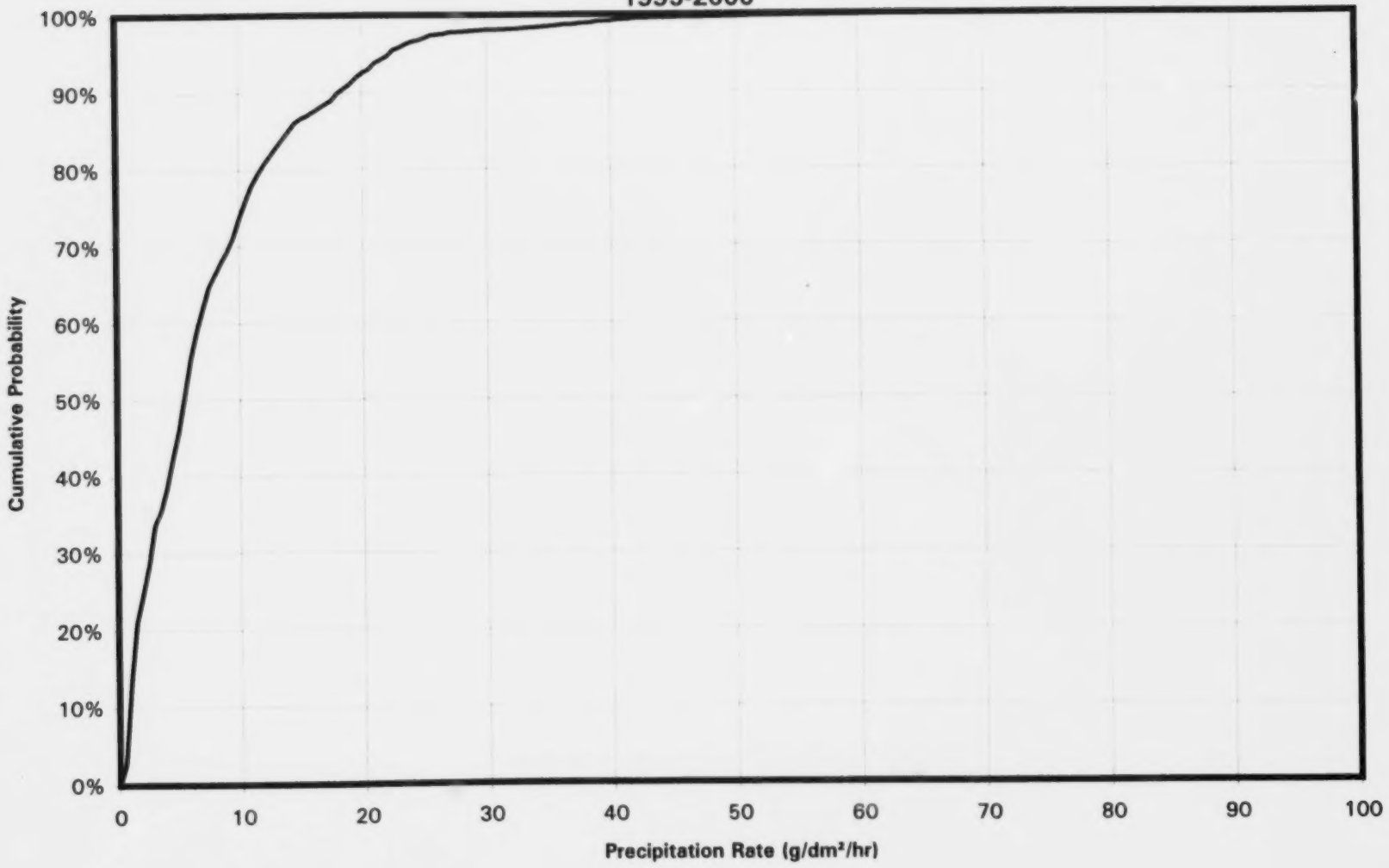
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 35 min Hist
11/09/00, 8:21 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

20-MINUTE RATE EVERY MINUTE

1995-2000



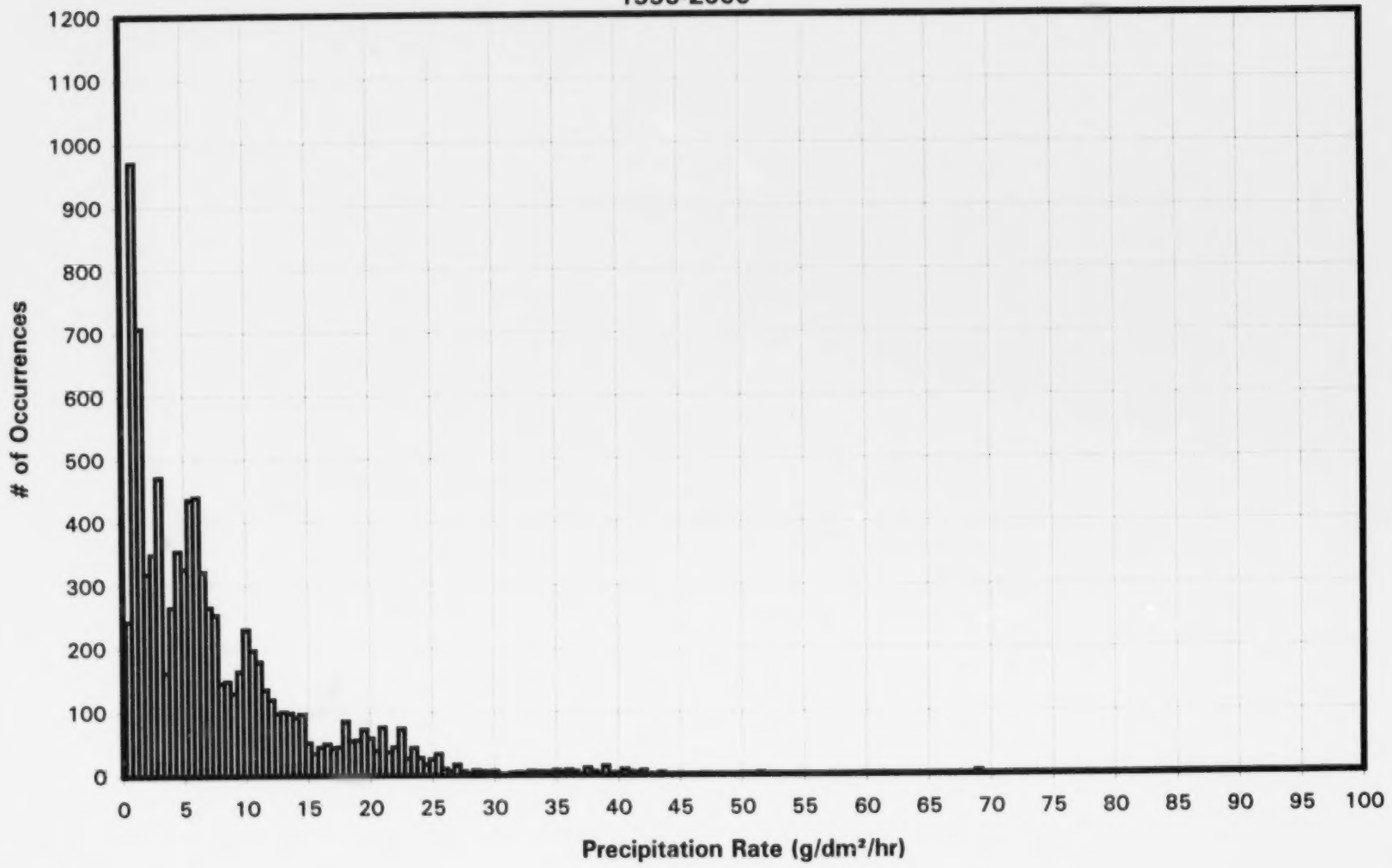
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 20 min Cuml.
11/09/00, 8:21 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

20-MINUTE RATE EVERY MINUTE

1995-2000



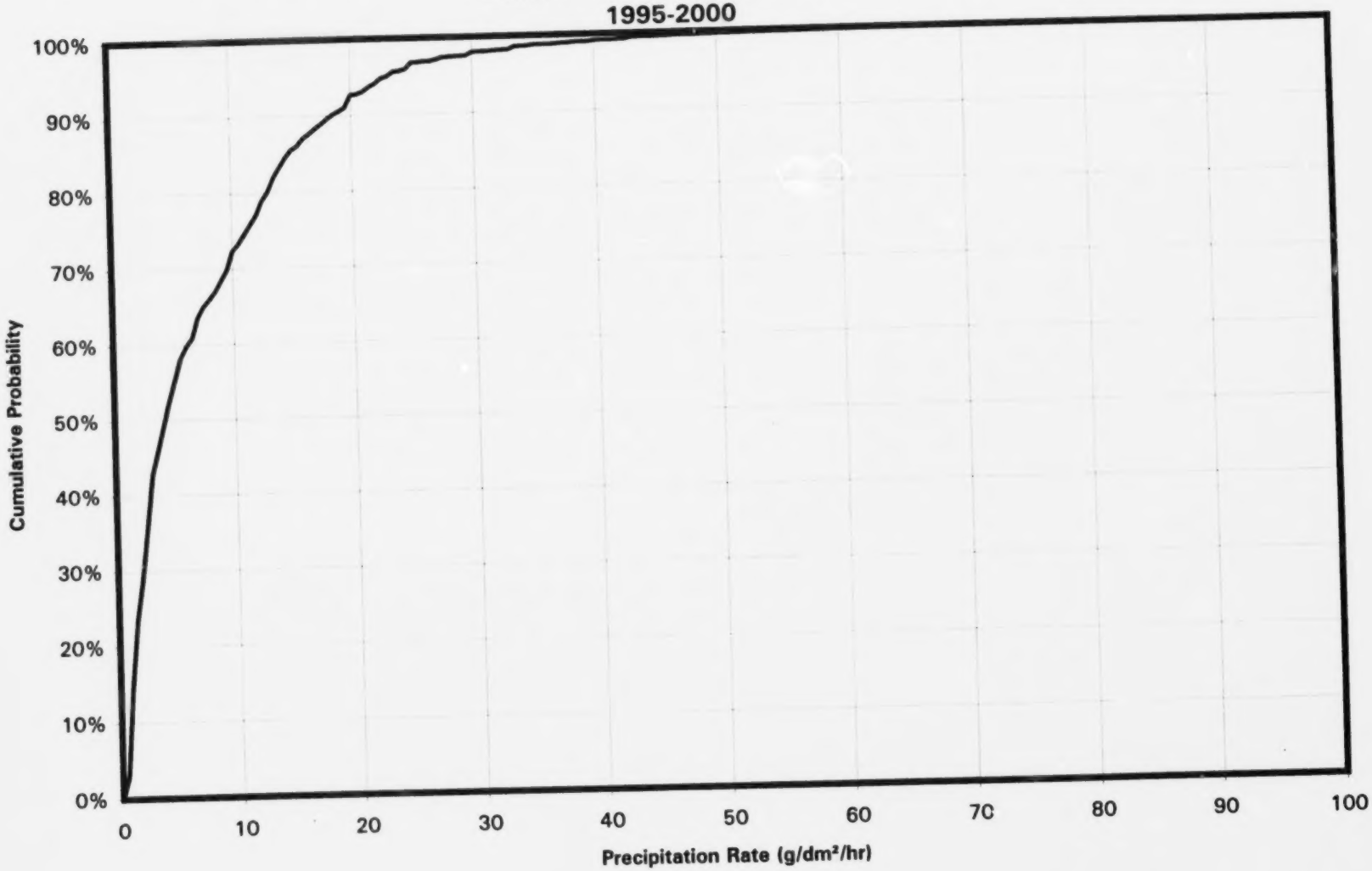
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 20 min Hist
11/09/00, 8:21 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

6-MINUTE RATE EVERY MINUTE

1995-2000



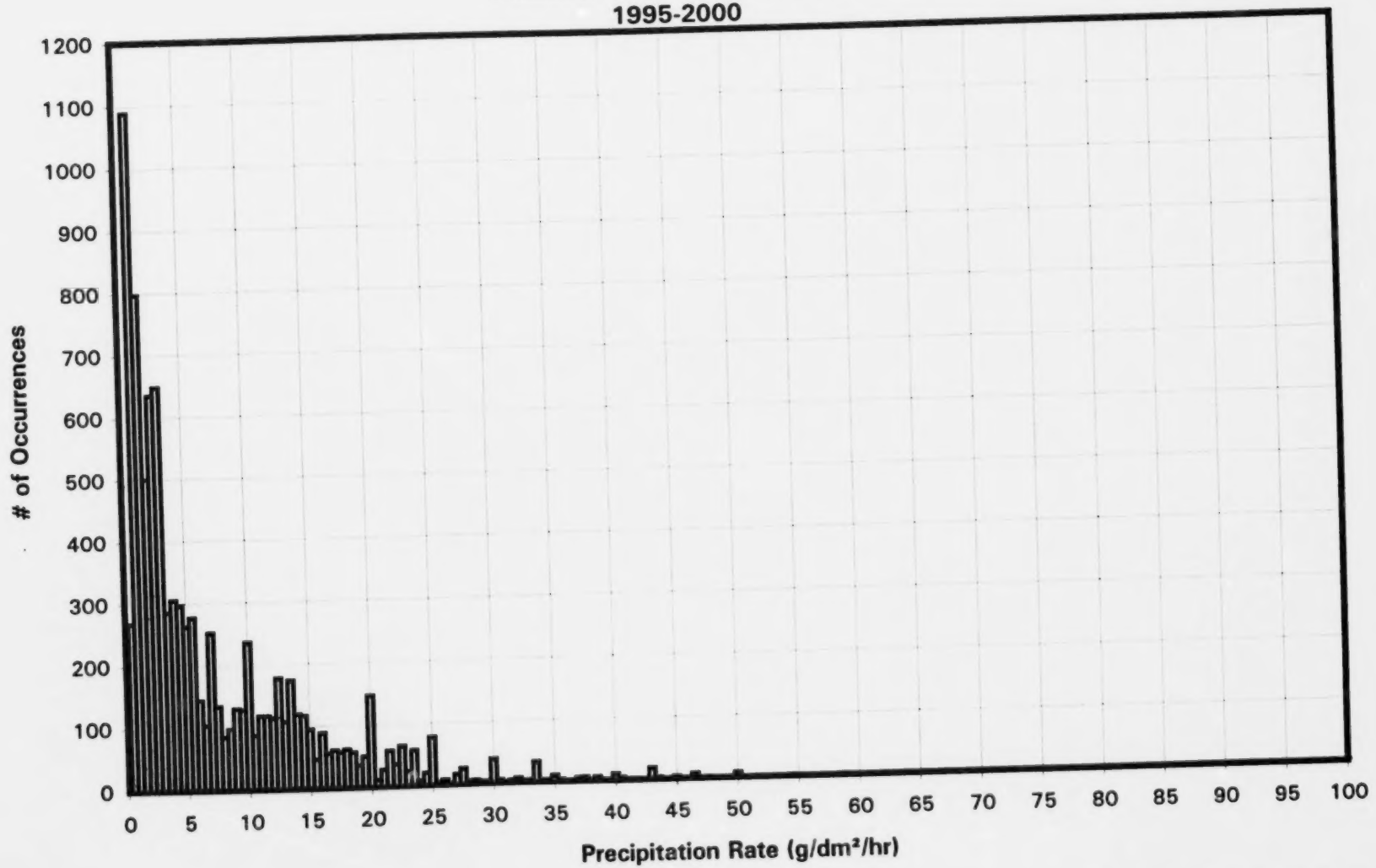
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 6 min Cuml.
11/09/00, 8:21 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -25°C

6-MINUTE RATE EVERY MINUTE

1995-2000



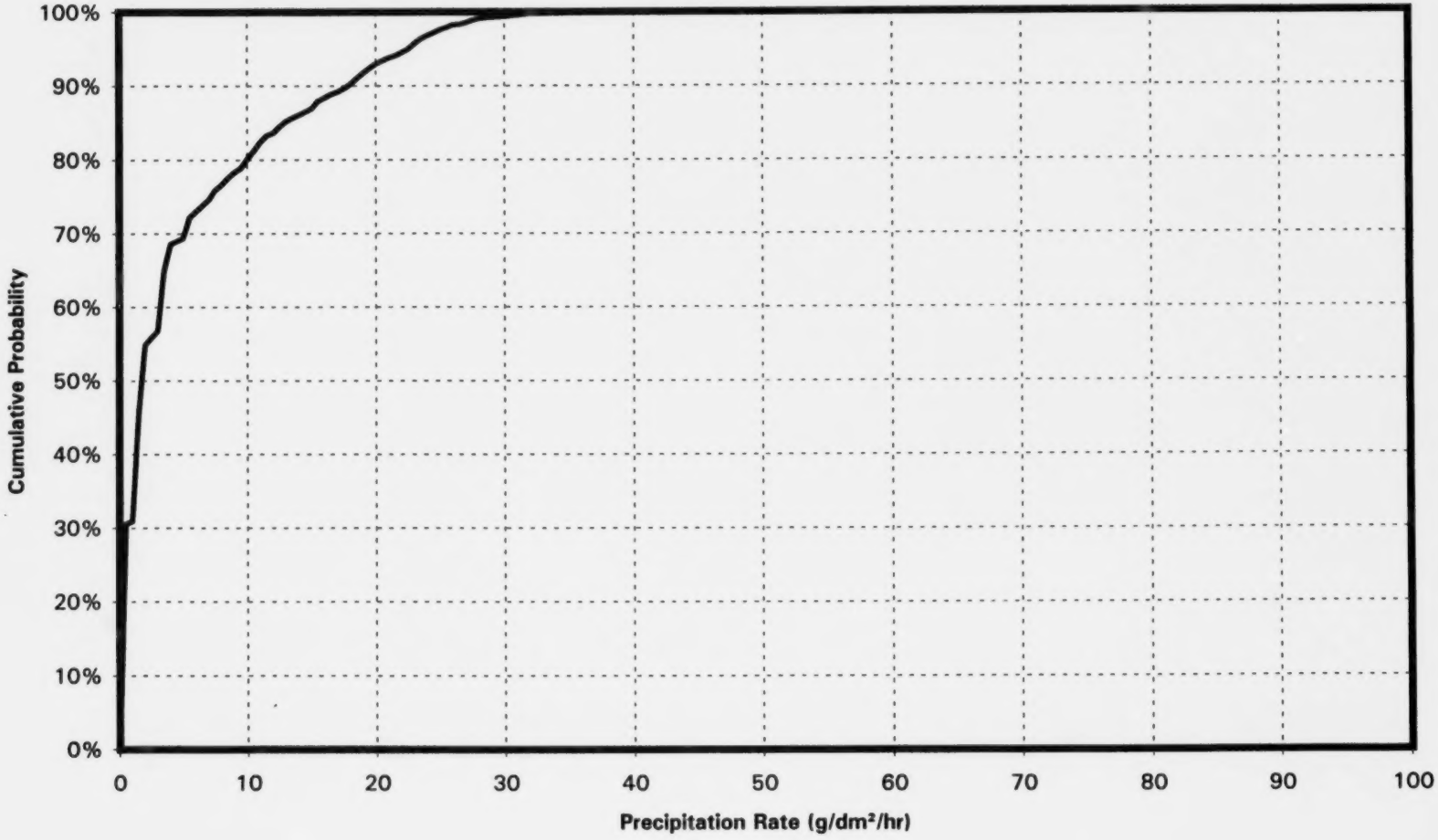
cm1589/analysis/readac/Snow Analysis (-14 to -25°C)
At: 6 min Hist
11/09/00, 8:21 AM

READADAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

35-MINUTE RATE EVERY MINUTE

1995-2000



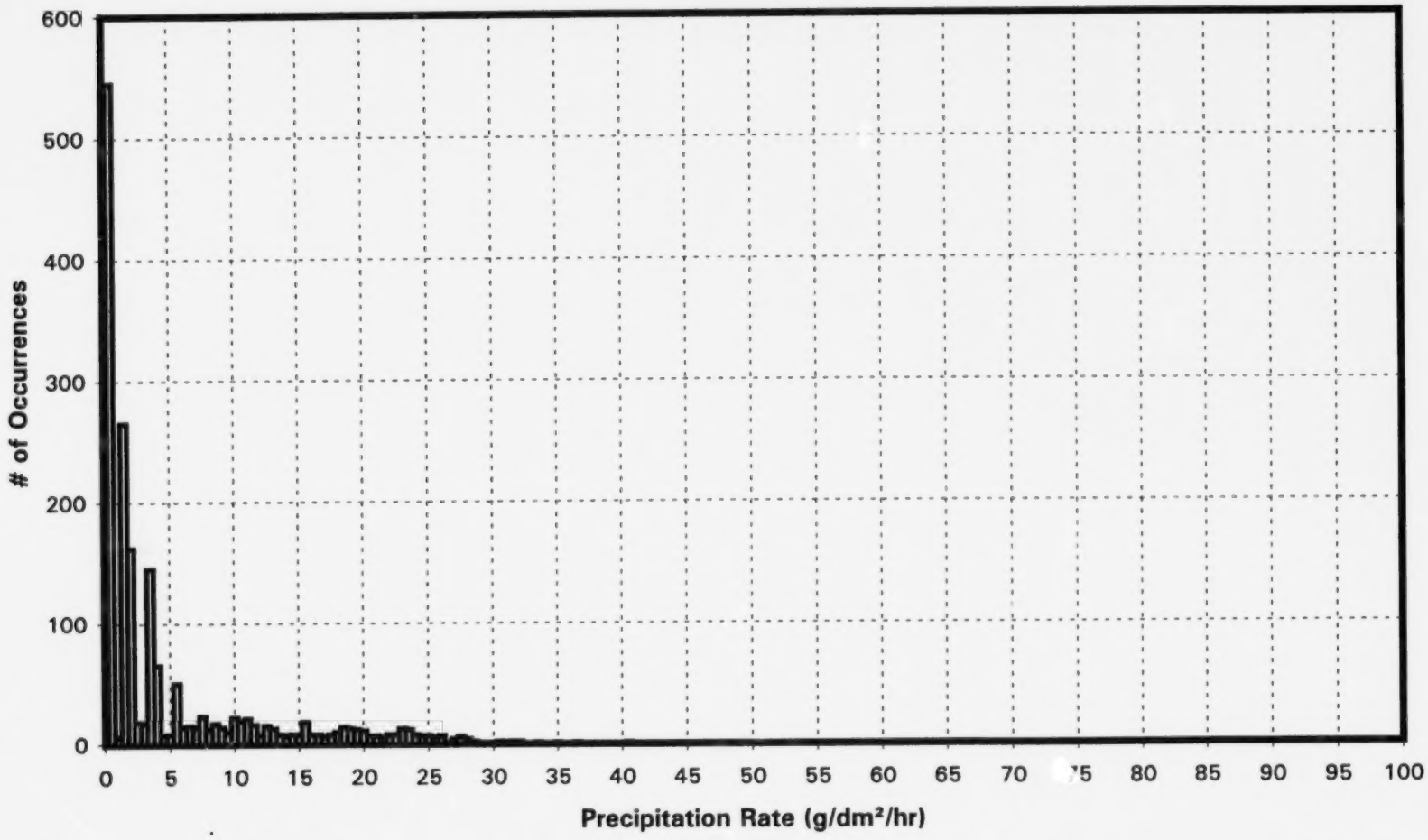
cm1589/anal;ysis/readac/Zr_-3.xls
At: 35 min Cuml.
6/27/02, 2:59 PM

READAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

35-MINUTE RATE EVERY MINUTE

1995-2000



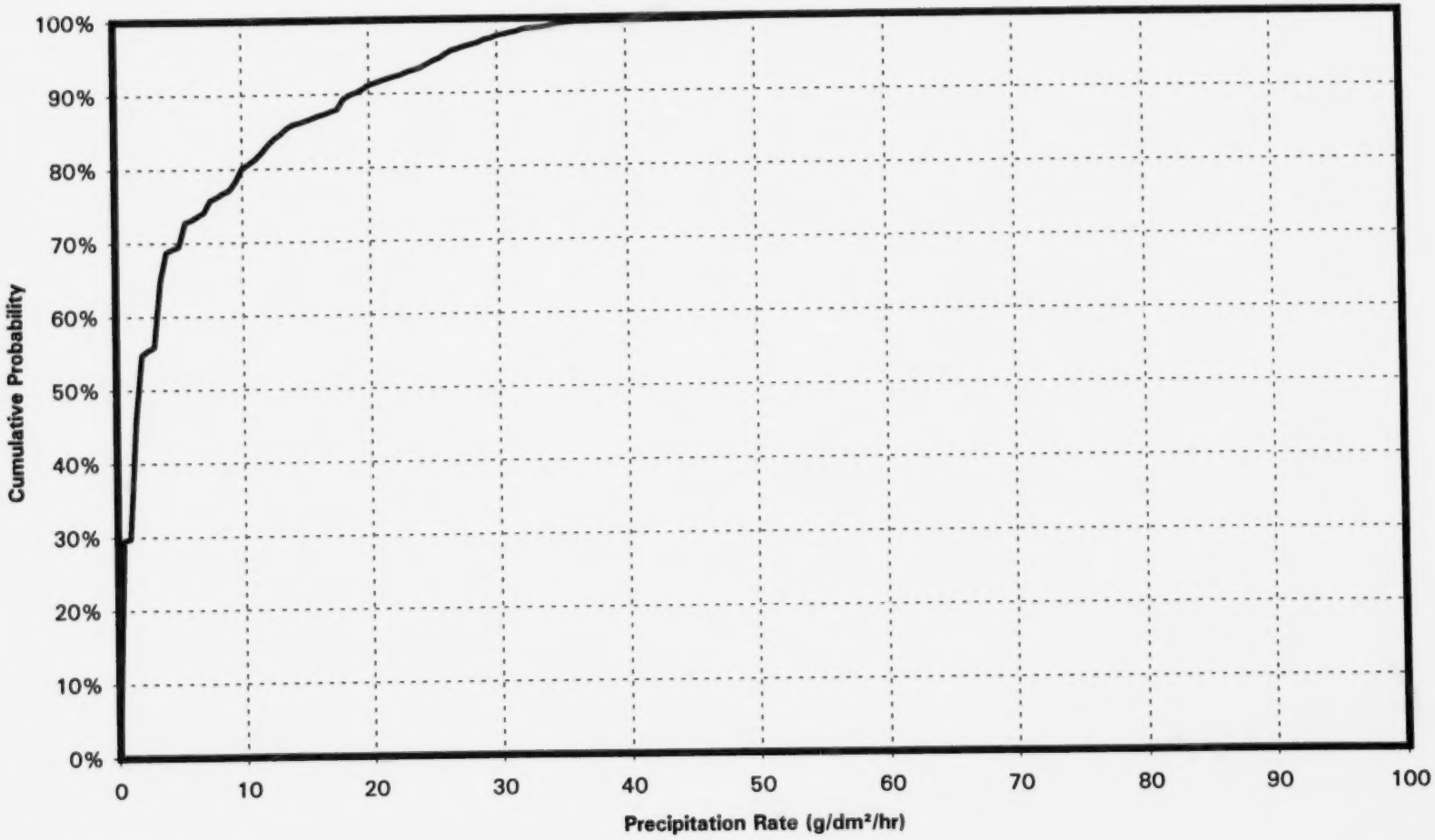
cm1589/anal;ysis/readac/Zr_-3.xls
At: 35 min Hist
6/27/02, 3:00 PM

READAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

20-MINUTE RATE EVERY MINUTE

1995-2000



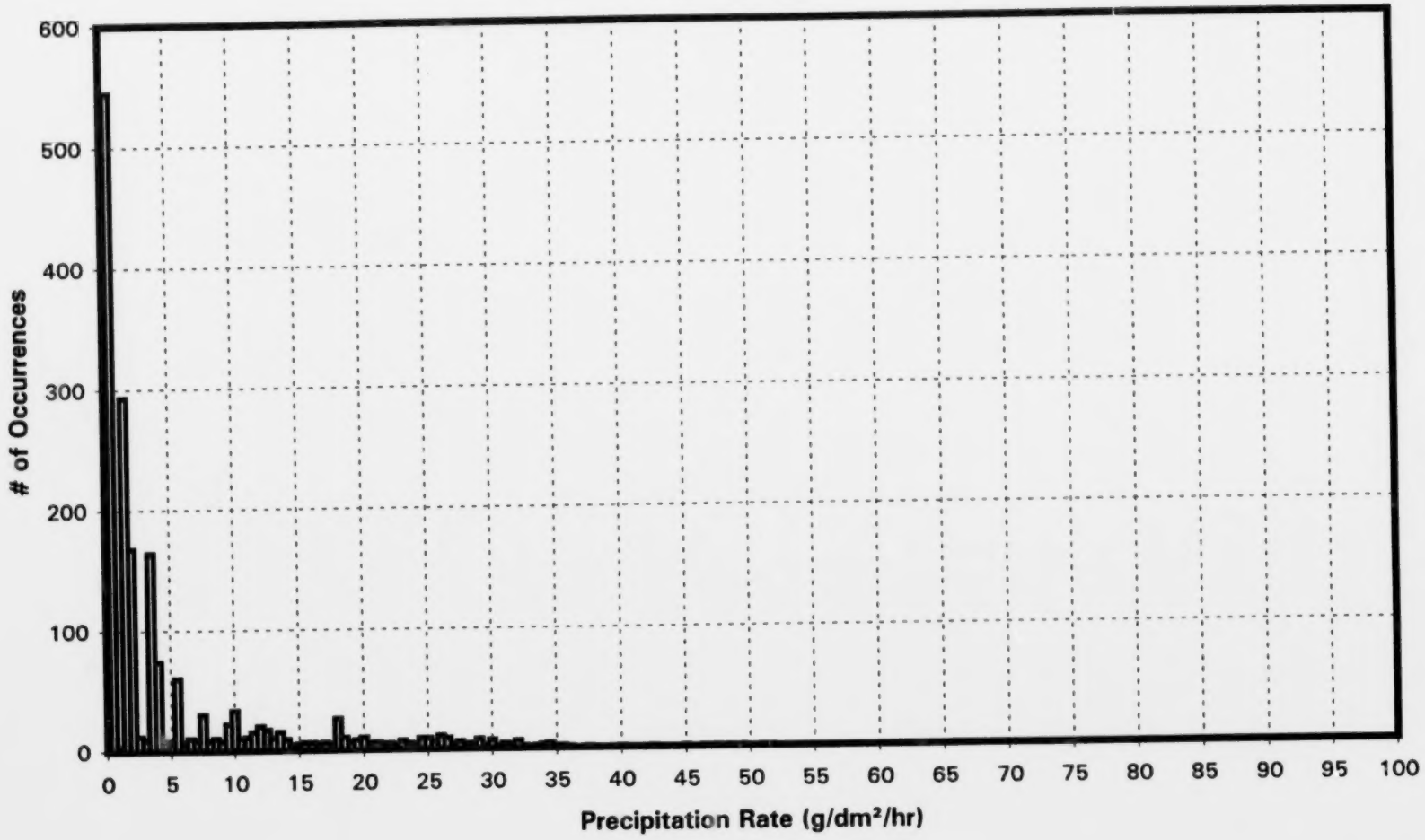
cm1589/anal;ysis/readac/Zr_-3.xls
At: 20 min Cuml.
6/27/02, 3:00 PM

READAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

20-MINUTE RATE EVERY MINUTE

1995-2000



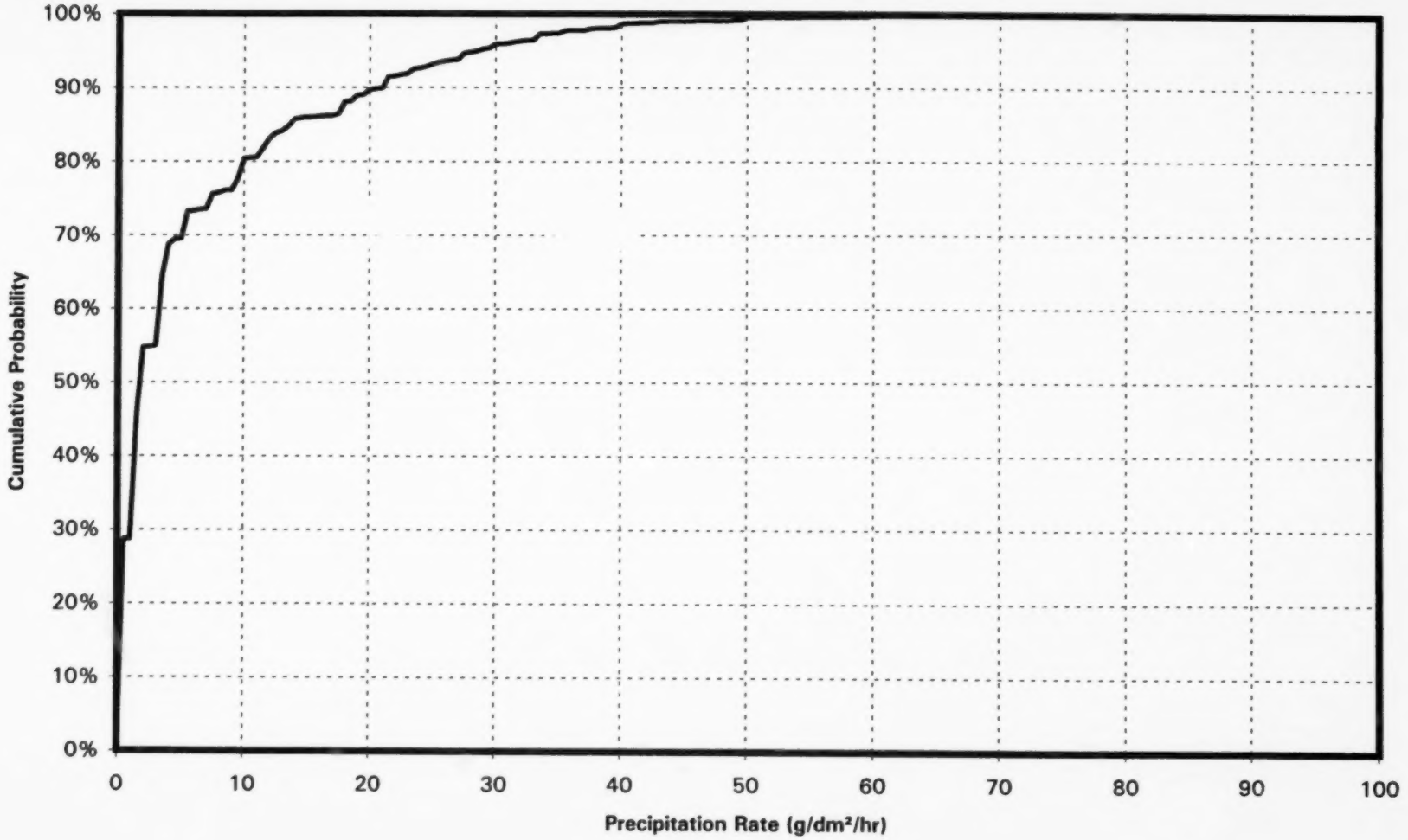
cm1589/anal;ysls/readac/Zr_-3.xls
At: 20 min Hist
6/27/02, 3:00 PM

READADAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

6-MINUTE RATE EVERY MINUTE

1995-2000



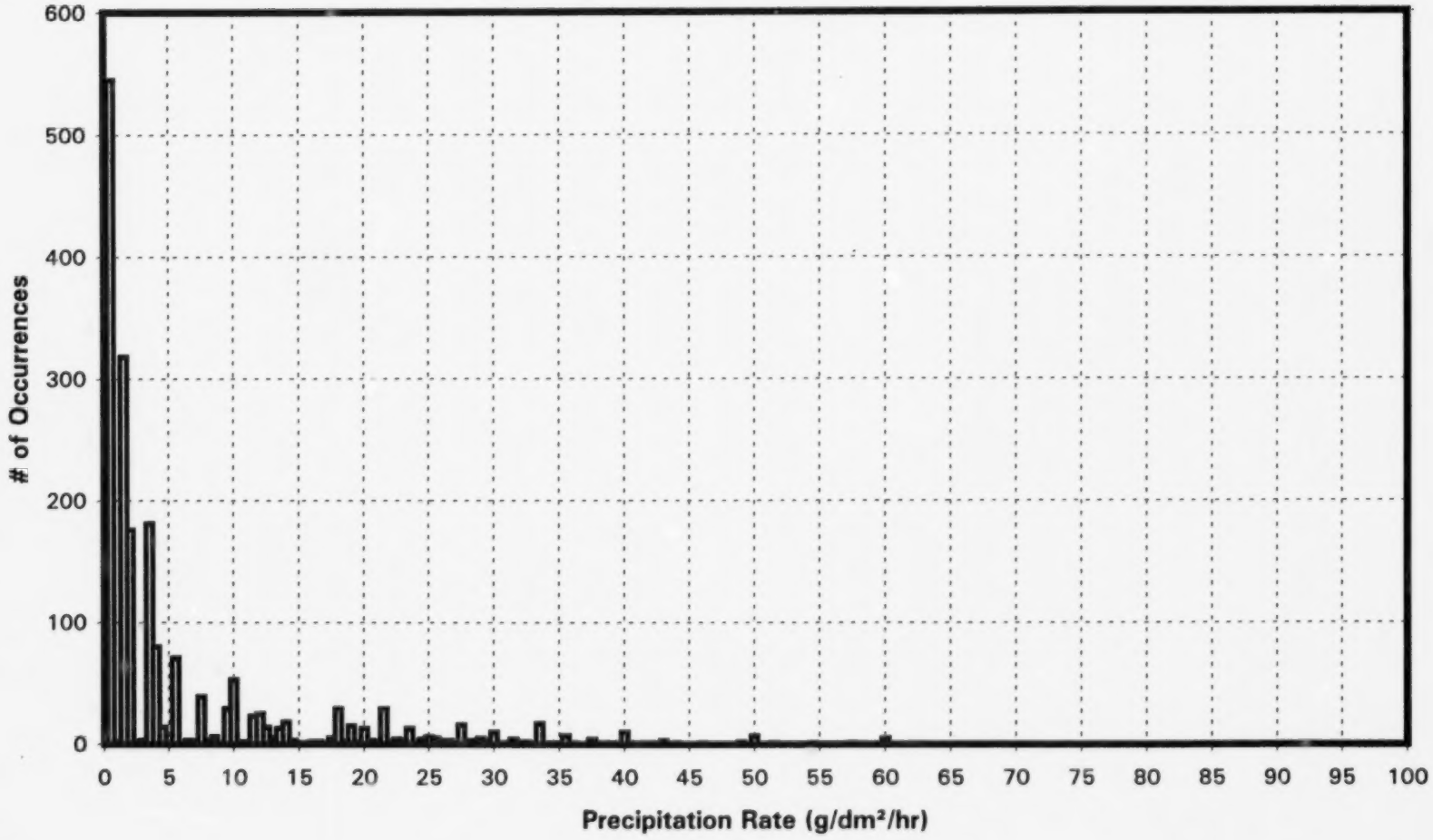
cm1589/anal;ysis/readac/Zr_-3.xls
At: 6 min Cuml.
6/27/02, 3:00 PM

READADAC ANALYSIS - LIGHT FREEZING RAIN

0 TO -3°C

6-MINUTE RATE EVERY MINUTE

1995-2000



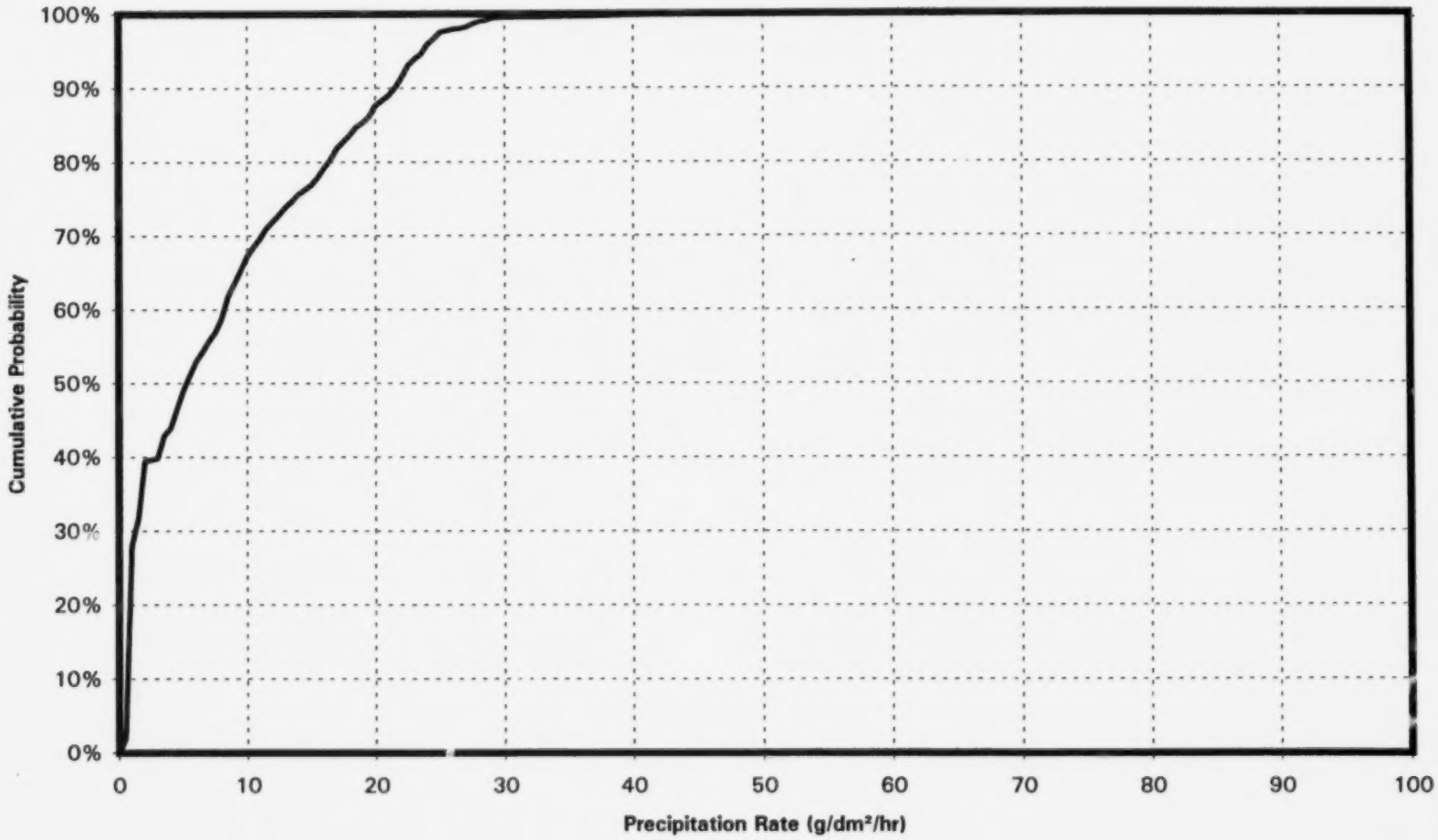
cm1589/analysis/readac/Zr_-3.xls
At: 6 min Hist
6/27/02, 3:01 PM

READAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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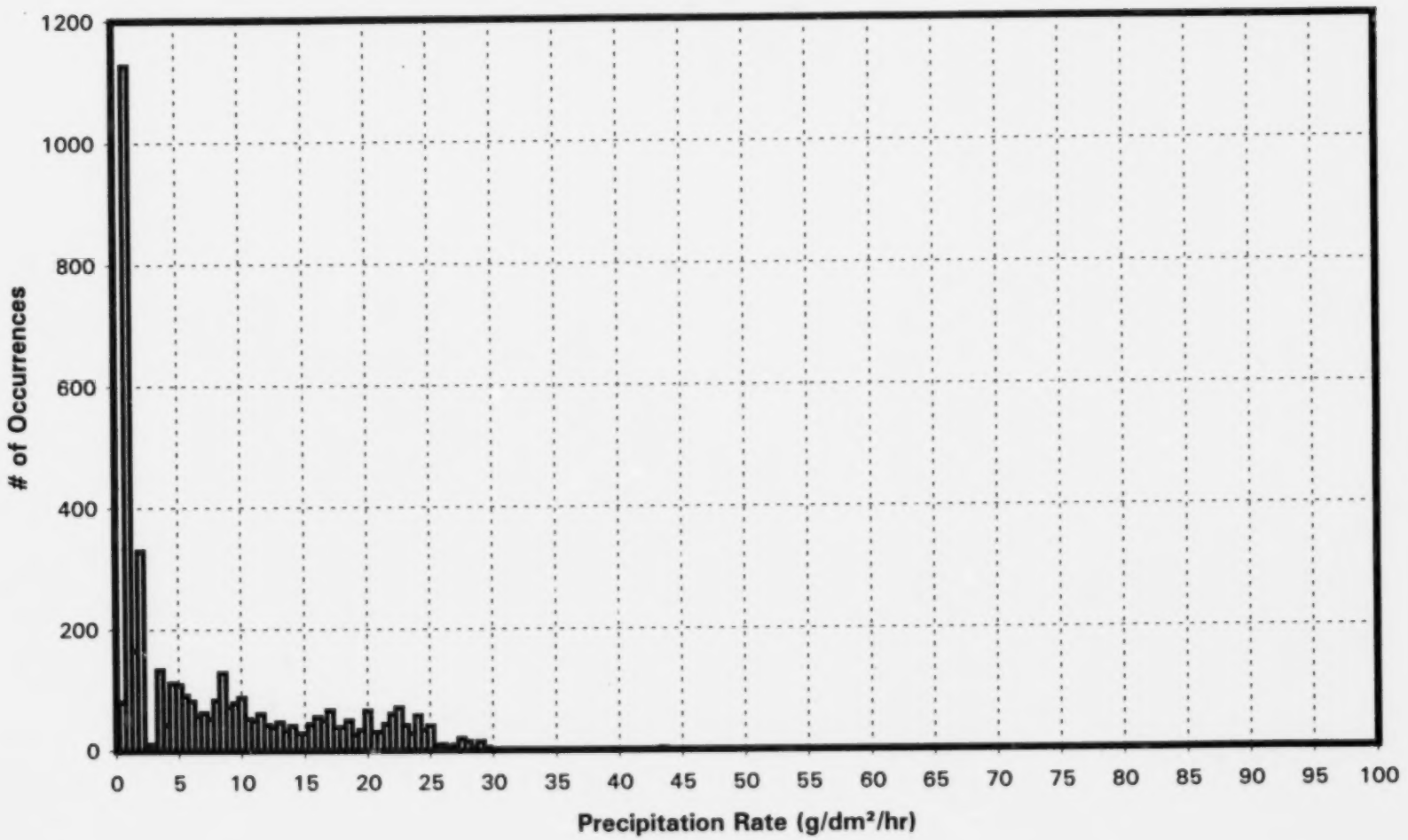
READADAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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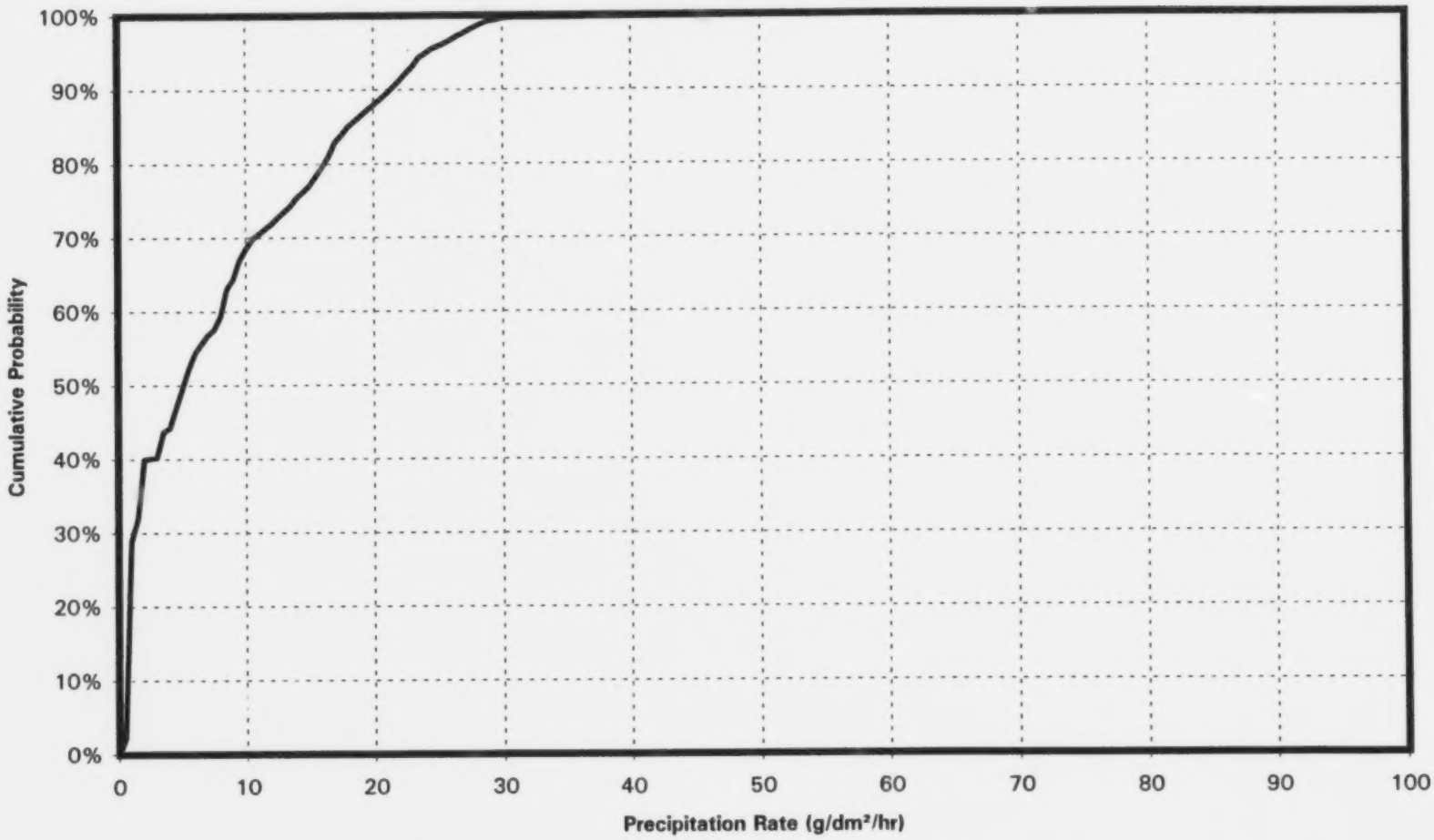
READAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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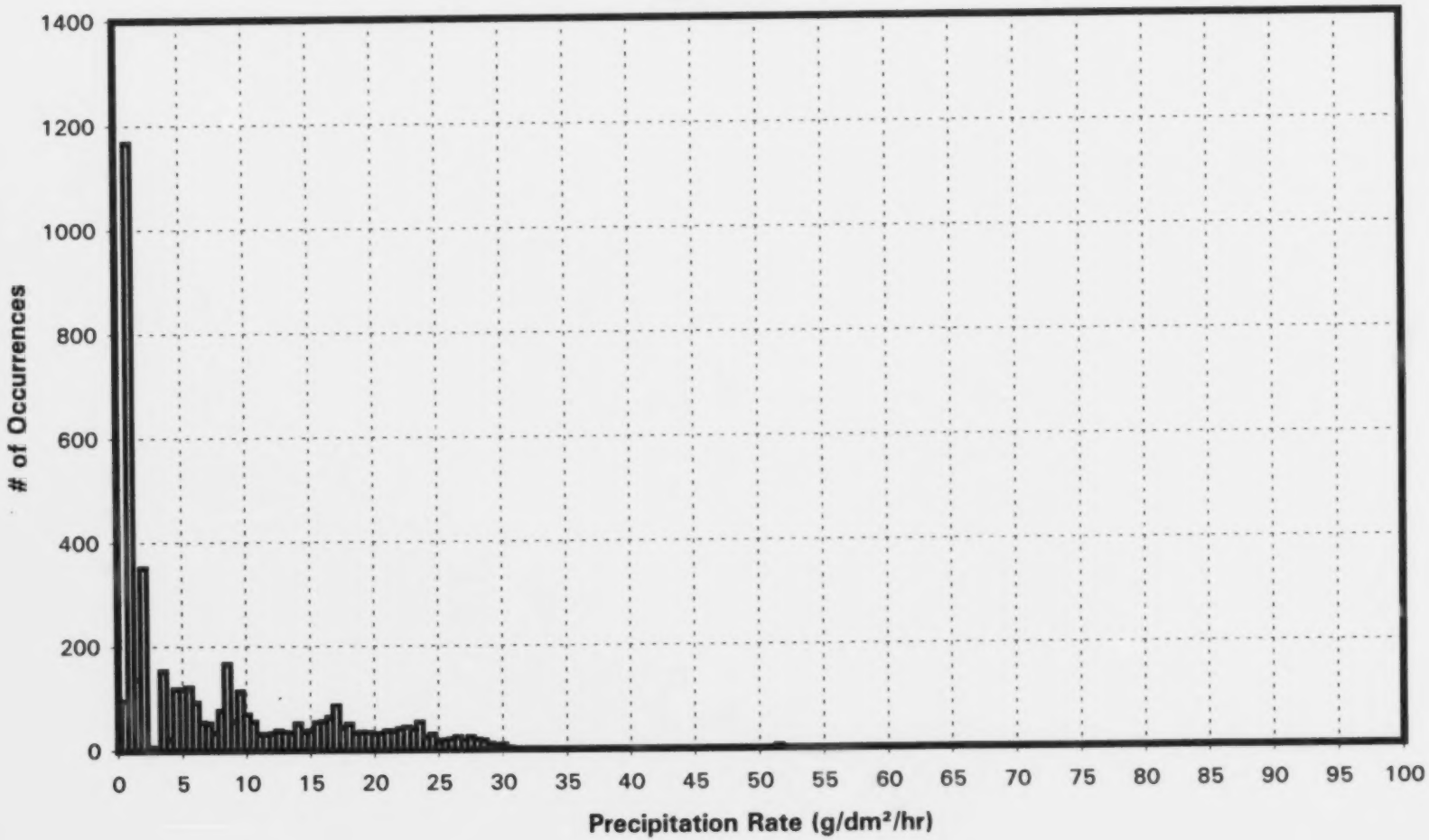
READAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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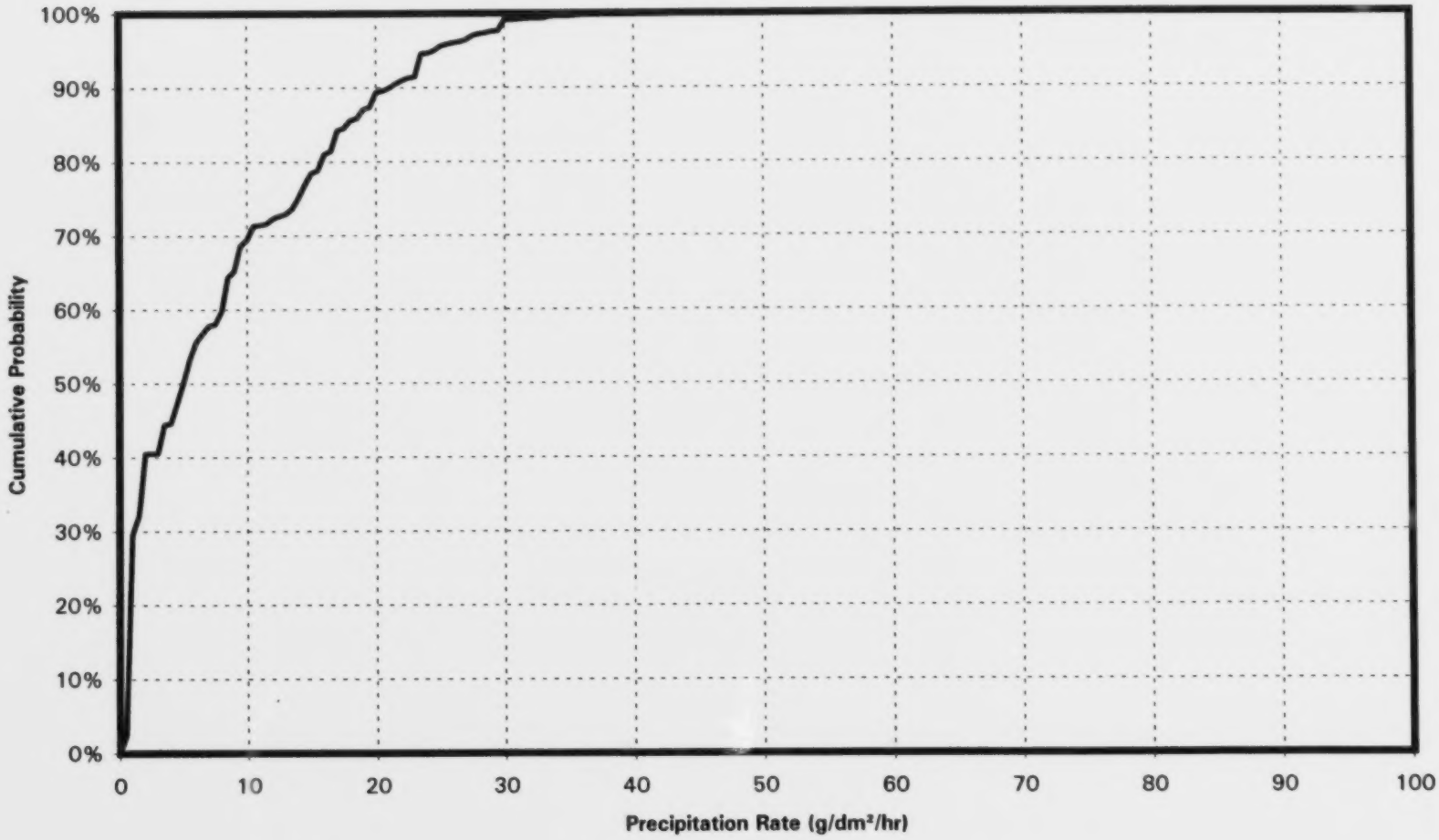
READAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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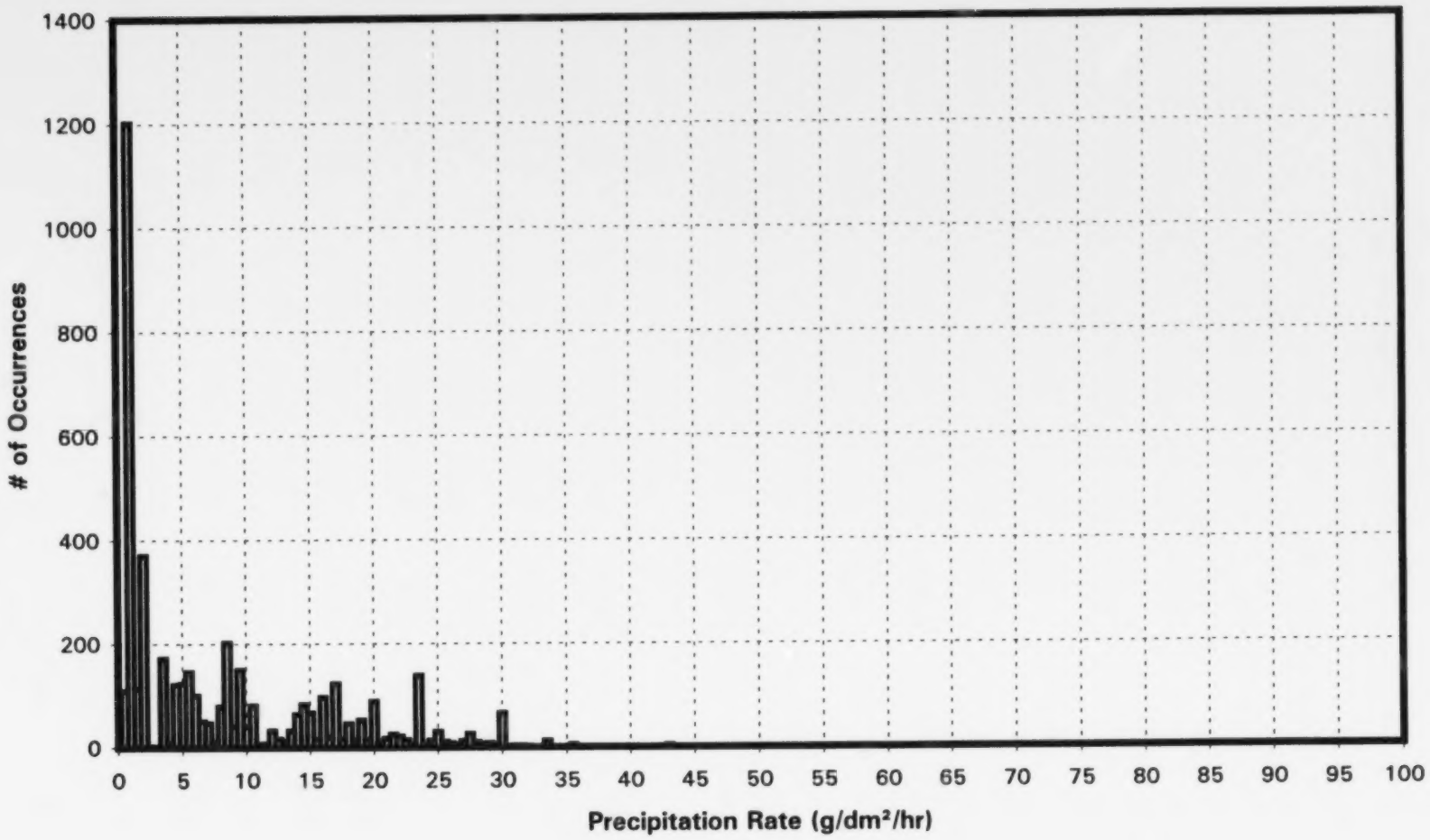
READAC ANALYSIS - LIGHT FREEZING RAIN

-3 TO -10°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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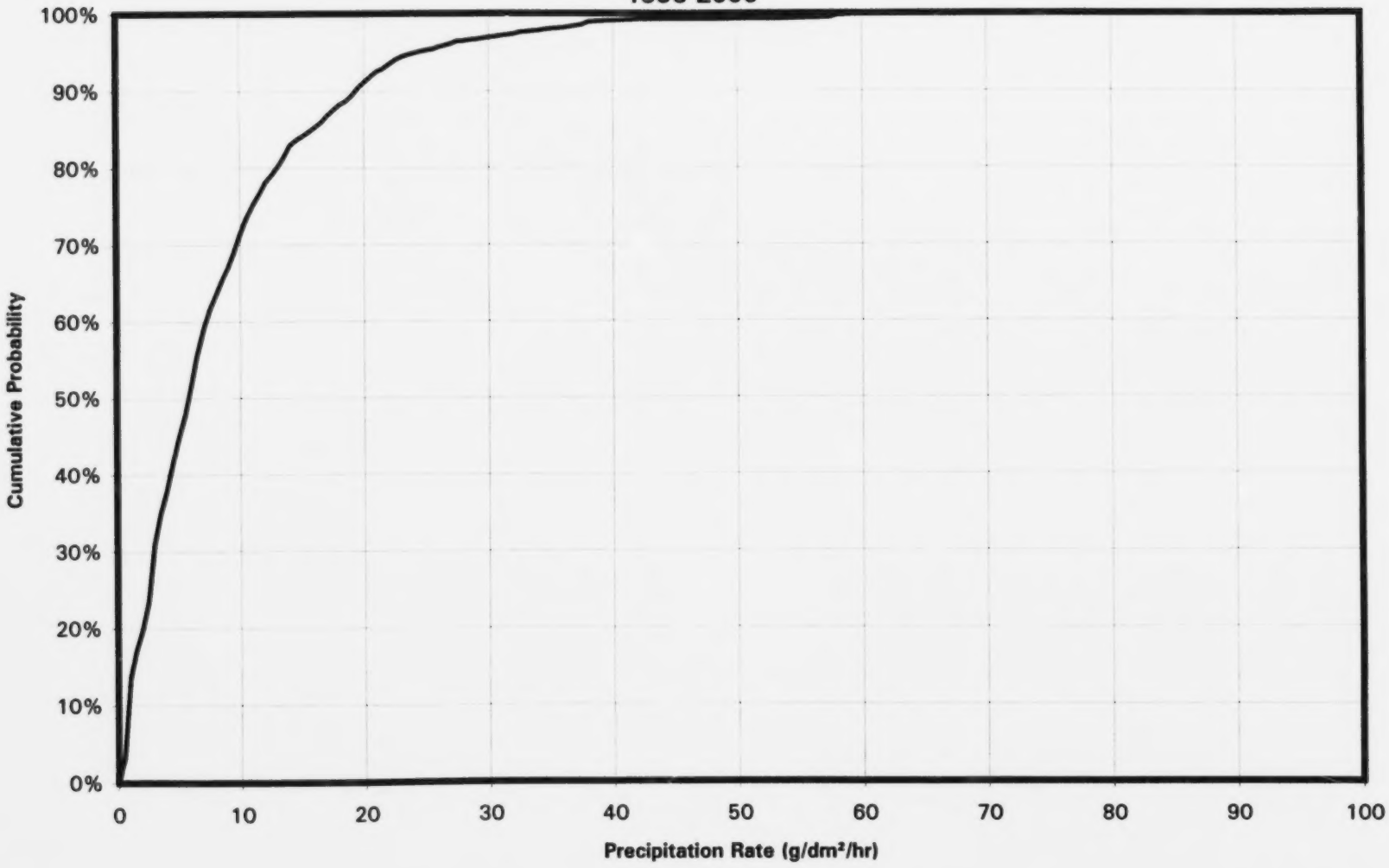
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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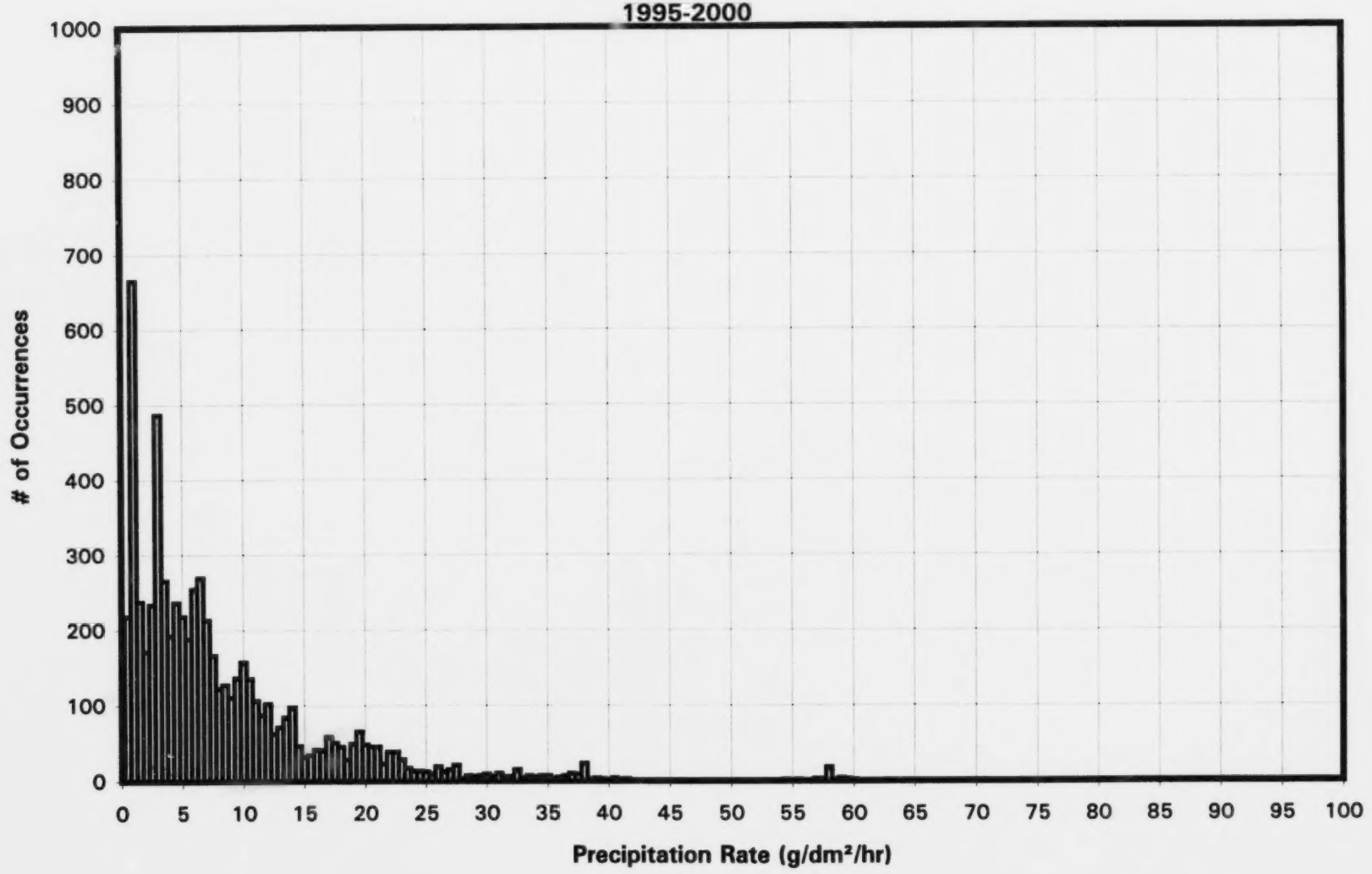
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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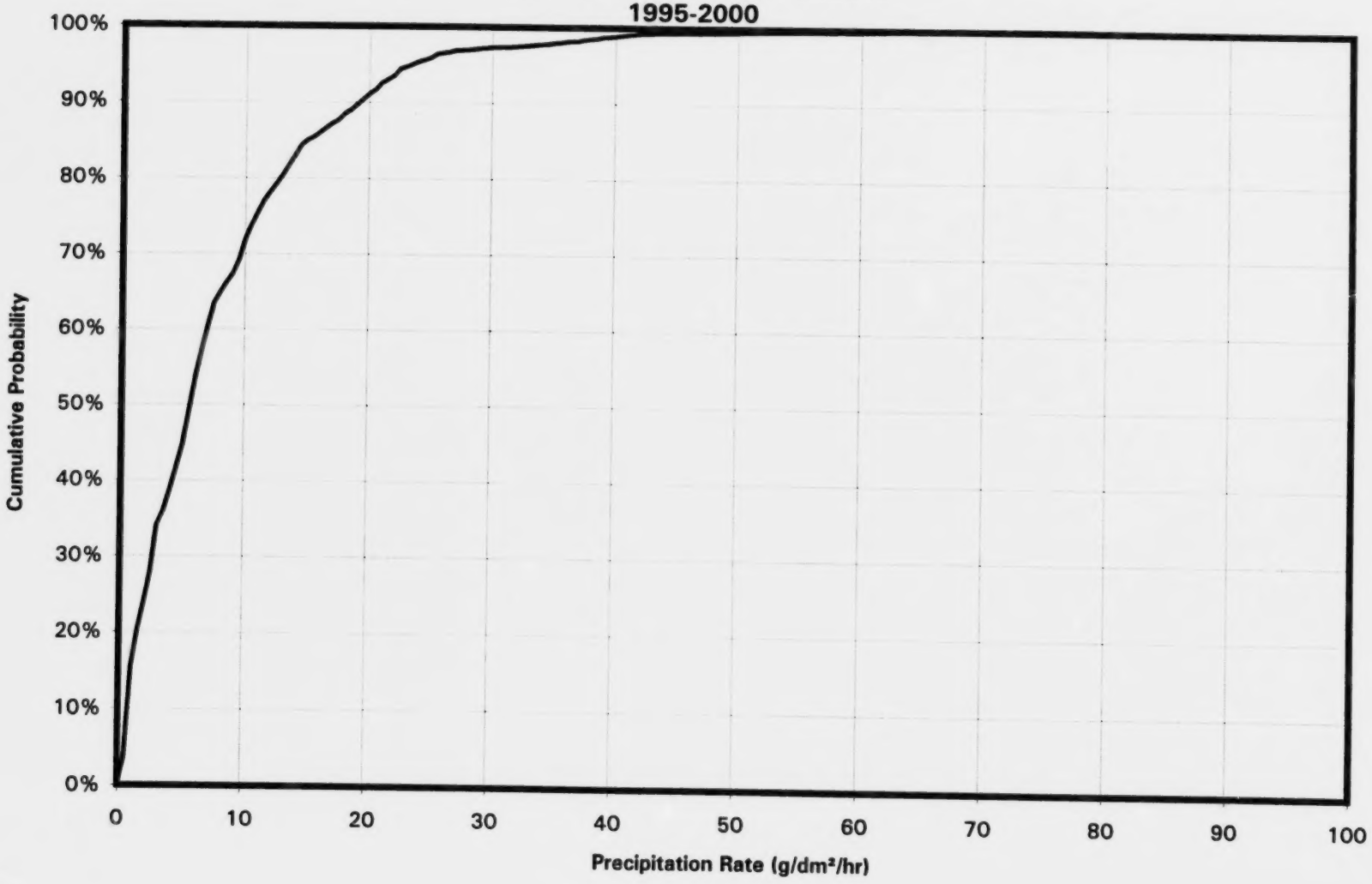
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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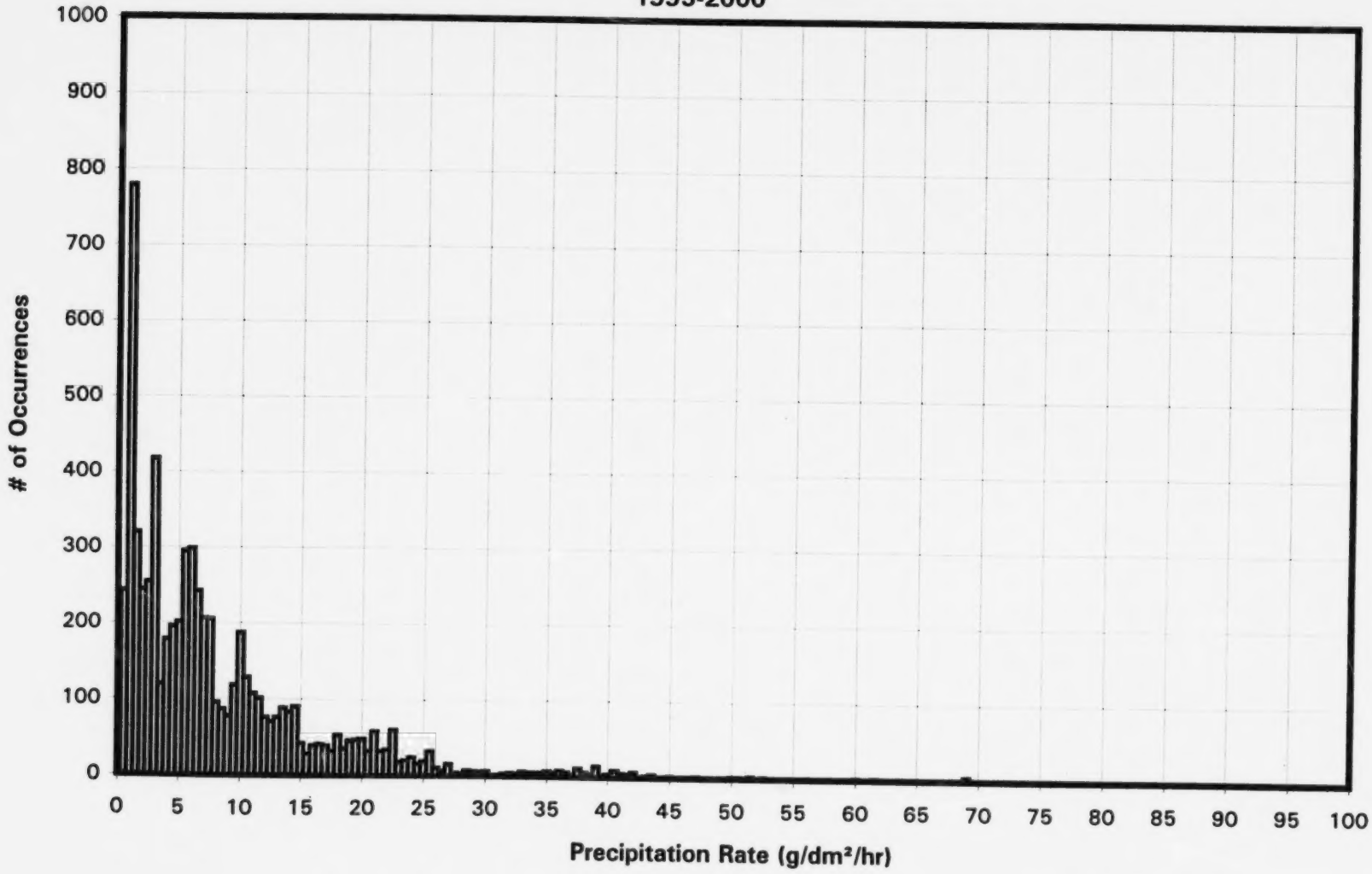
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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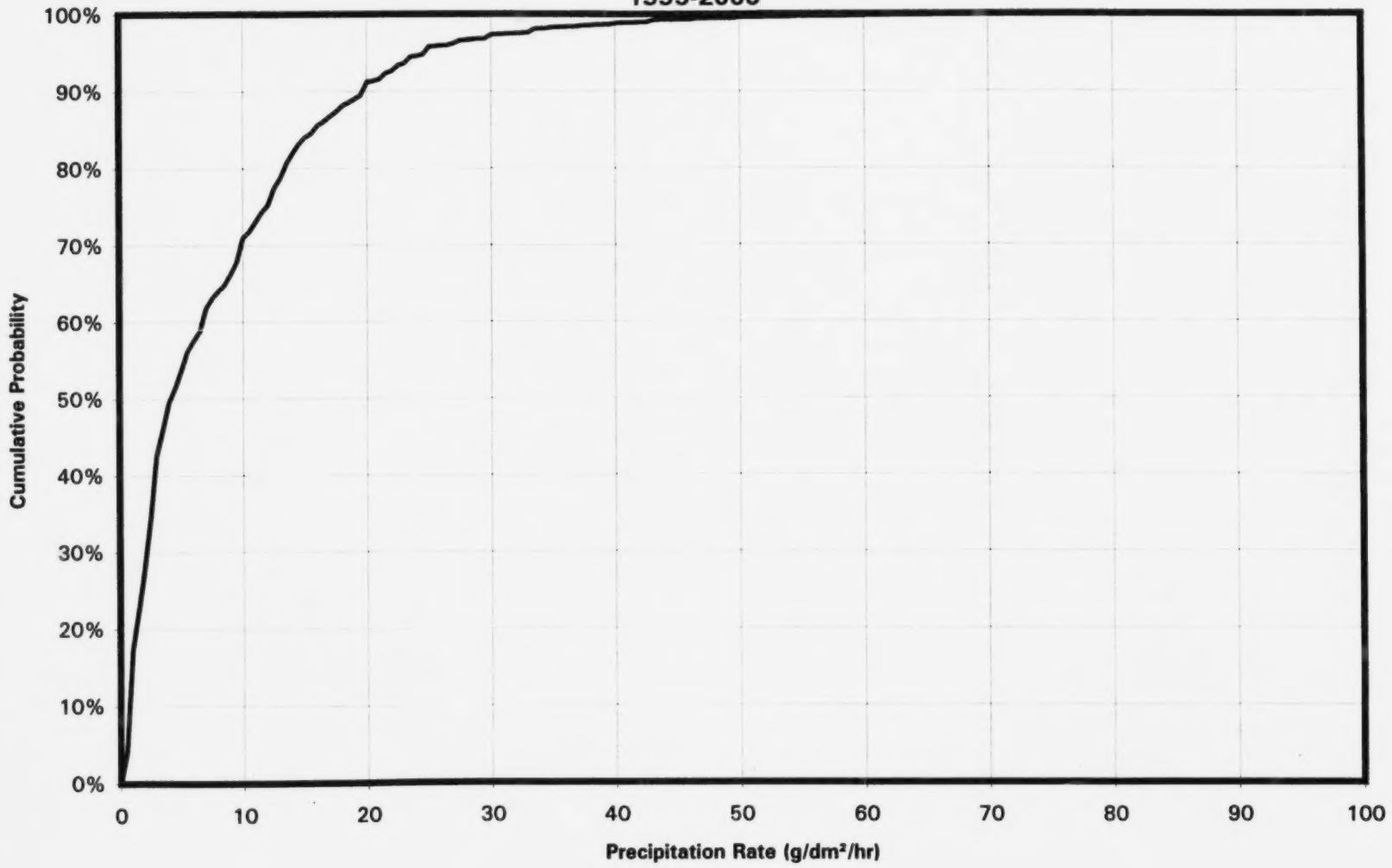
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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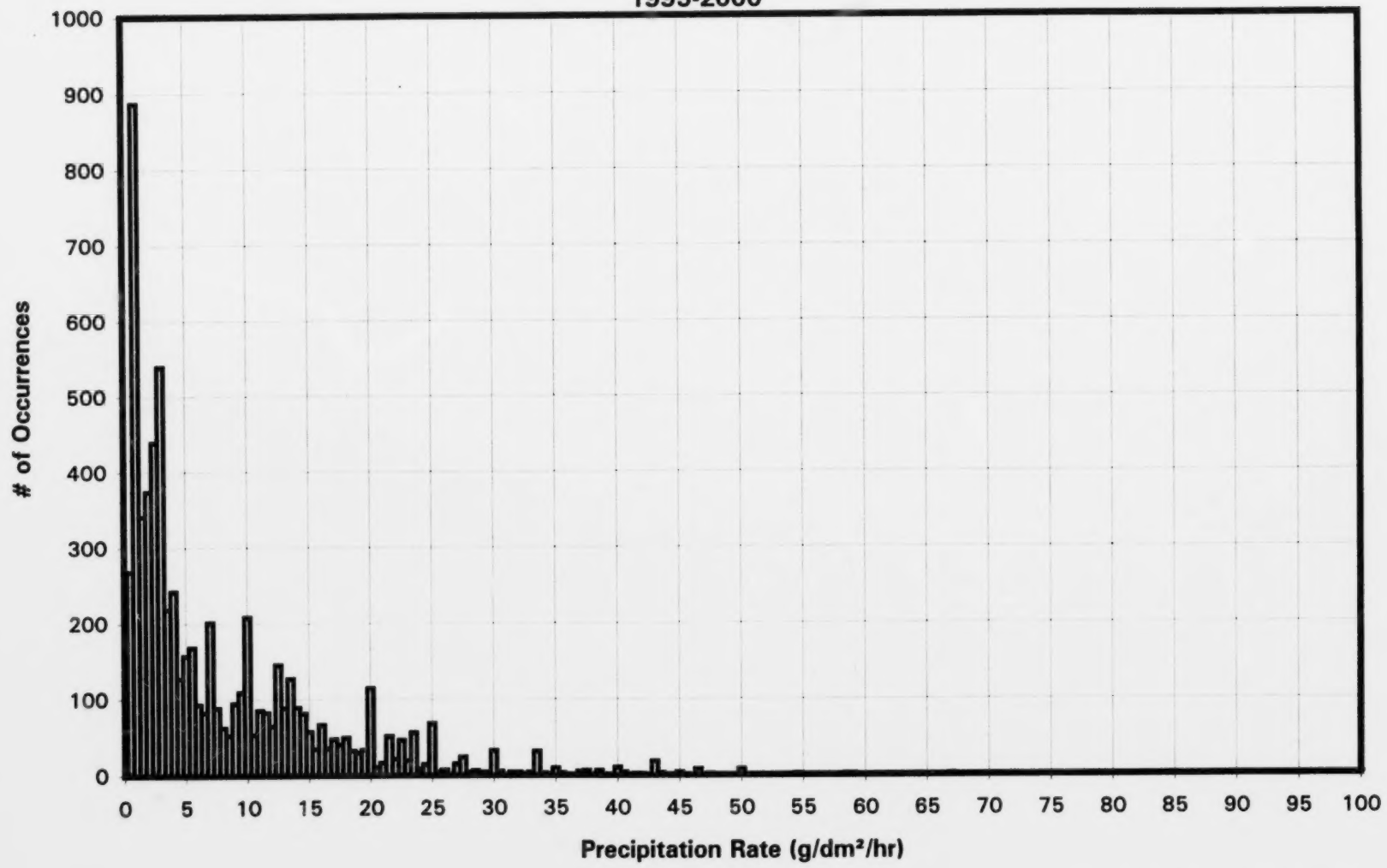
READAC AND CR21X ANALYSIS - NATURAL SNOW

-14 TO -18°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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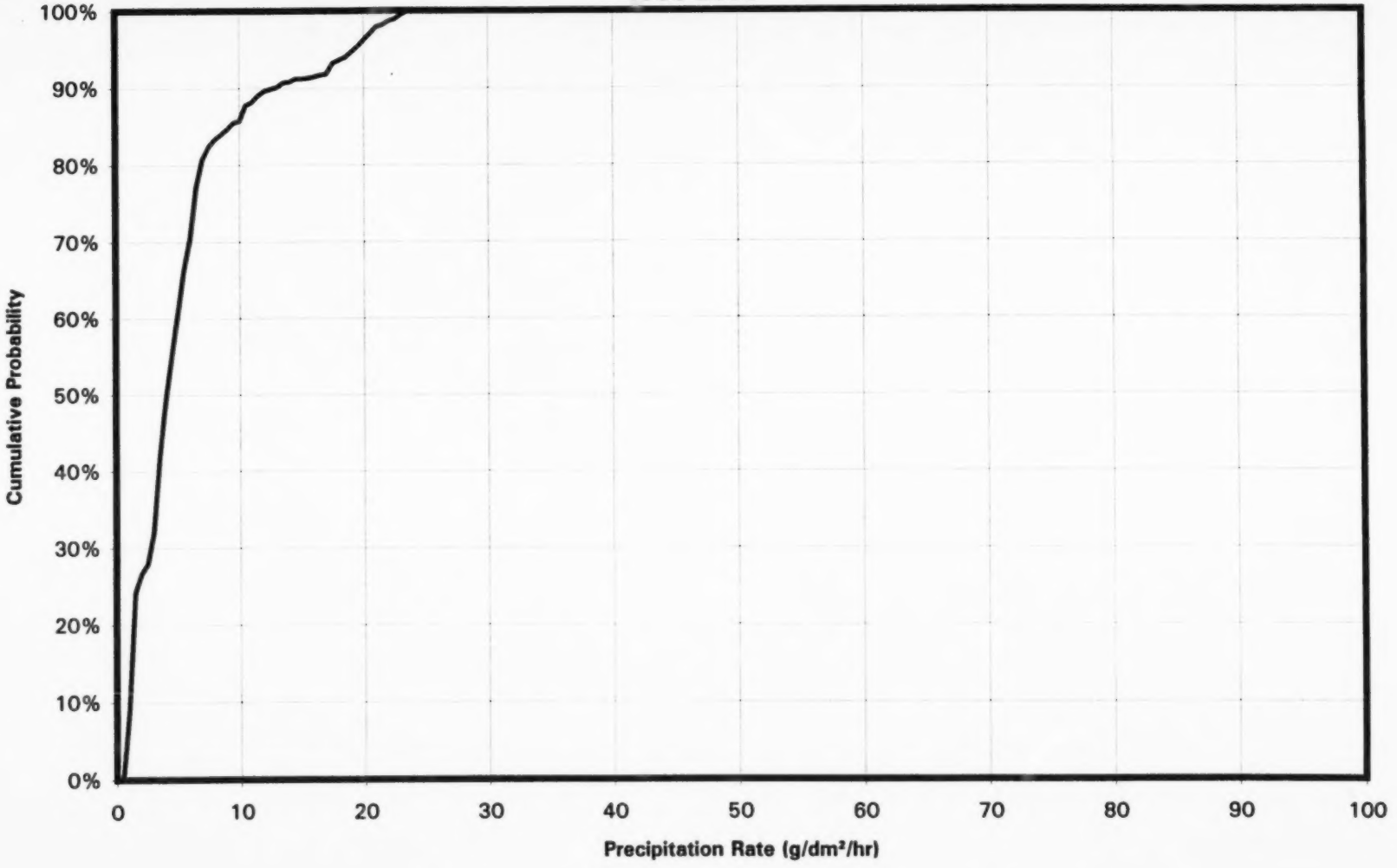
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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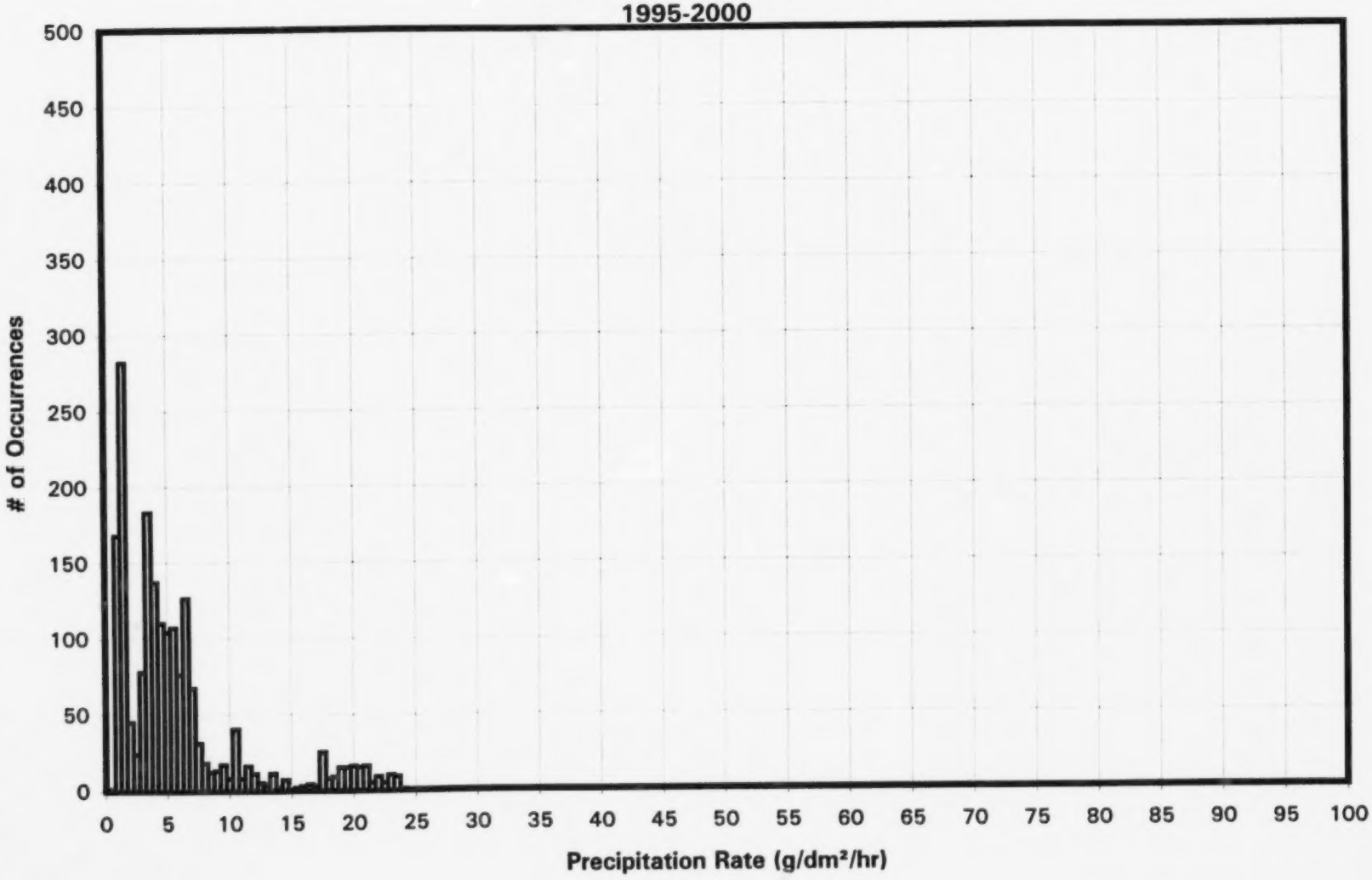
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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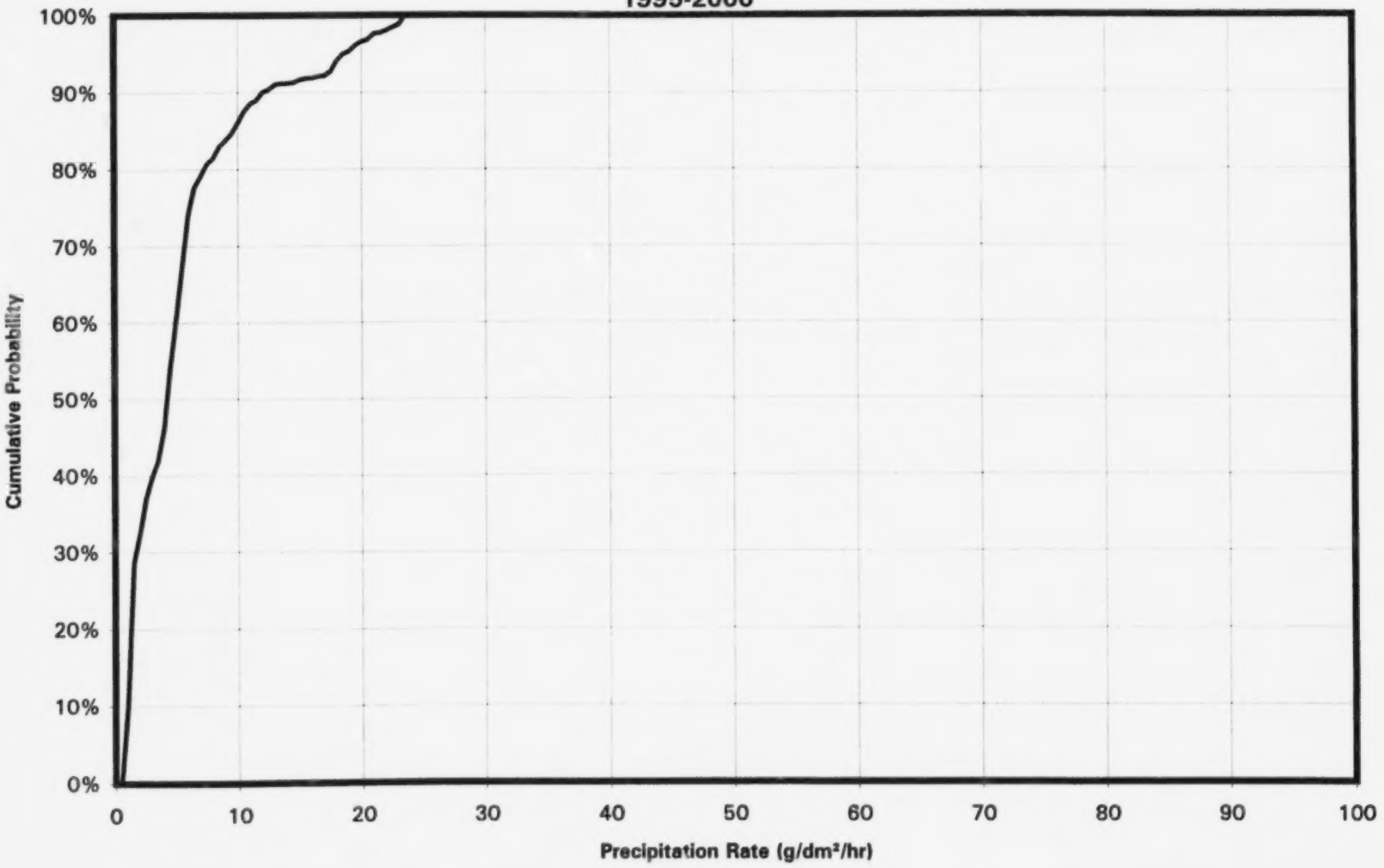
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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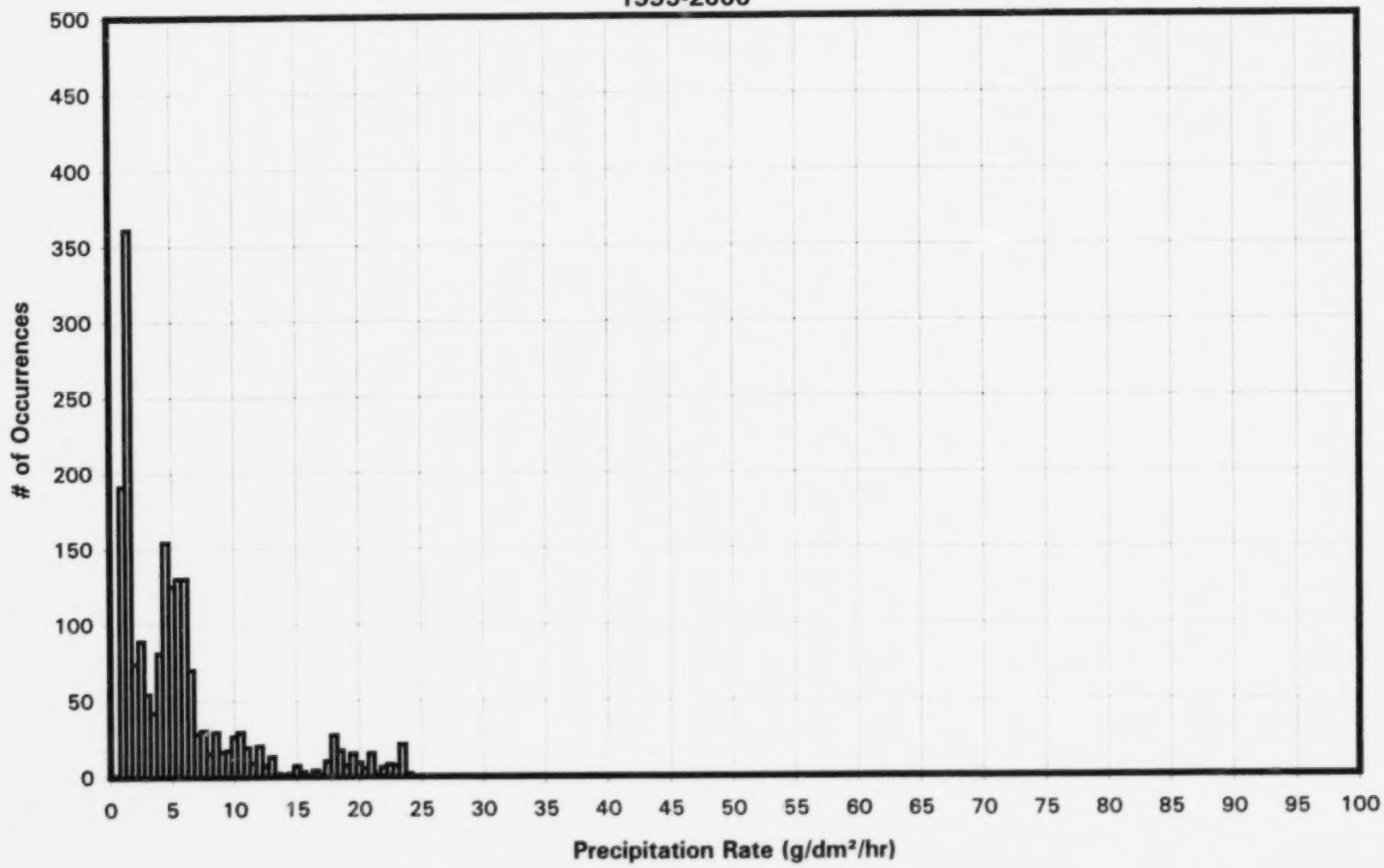
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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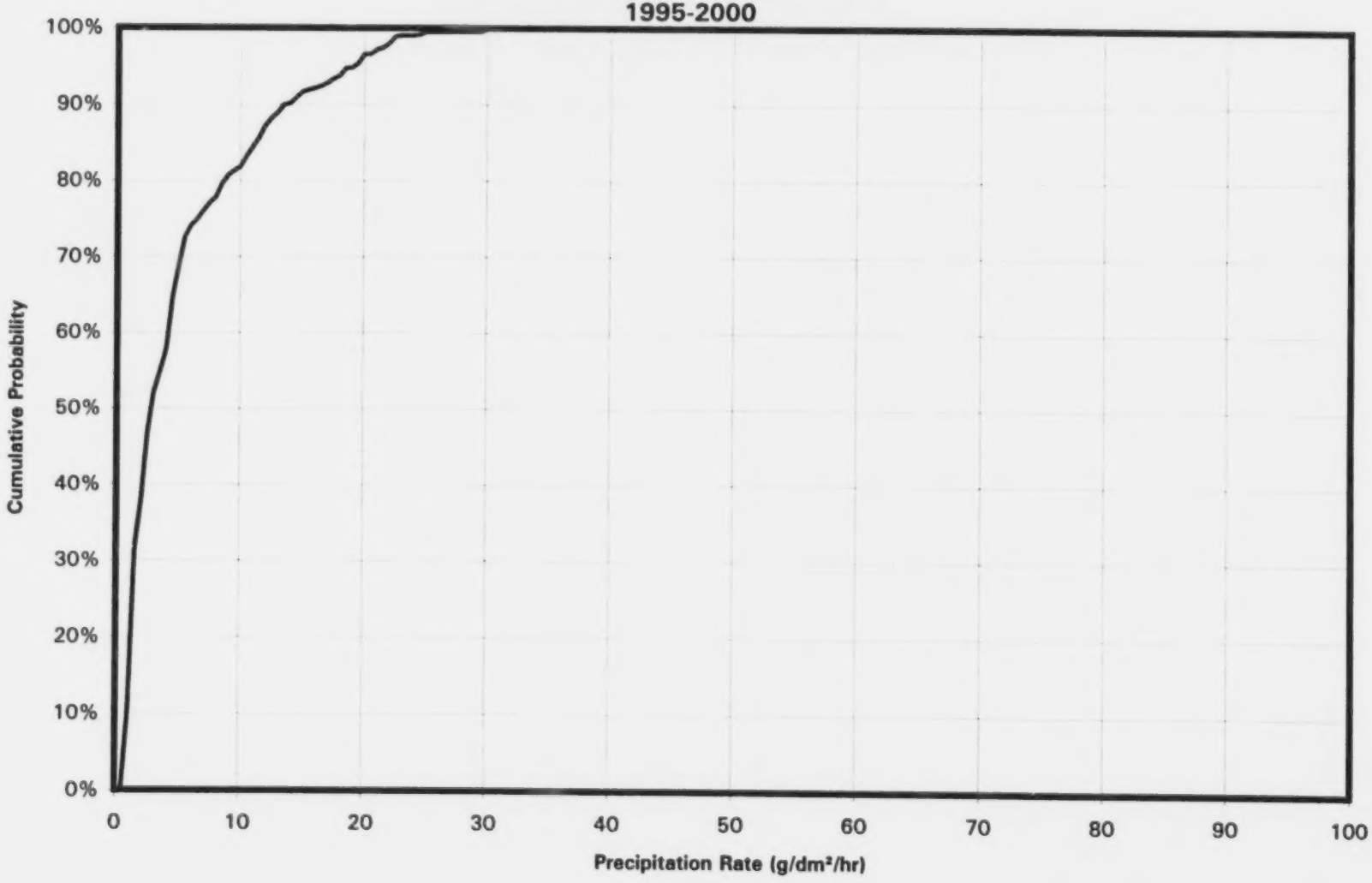
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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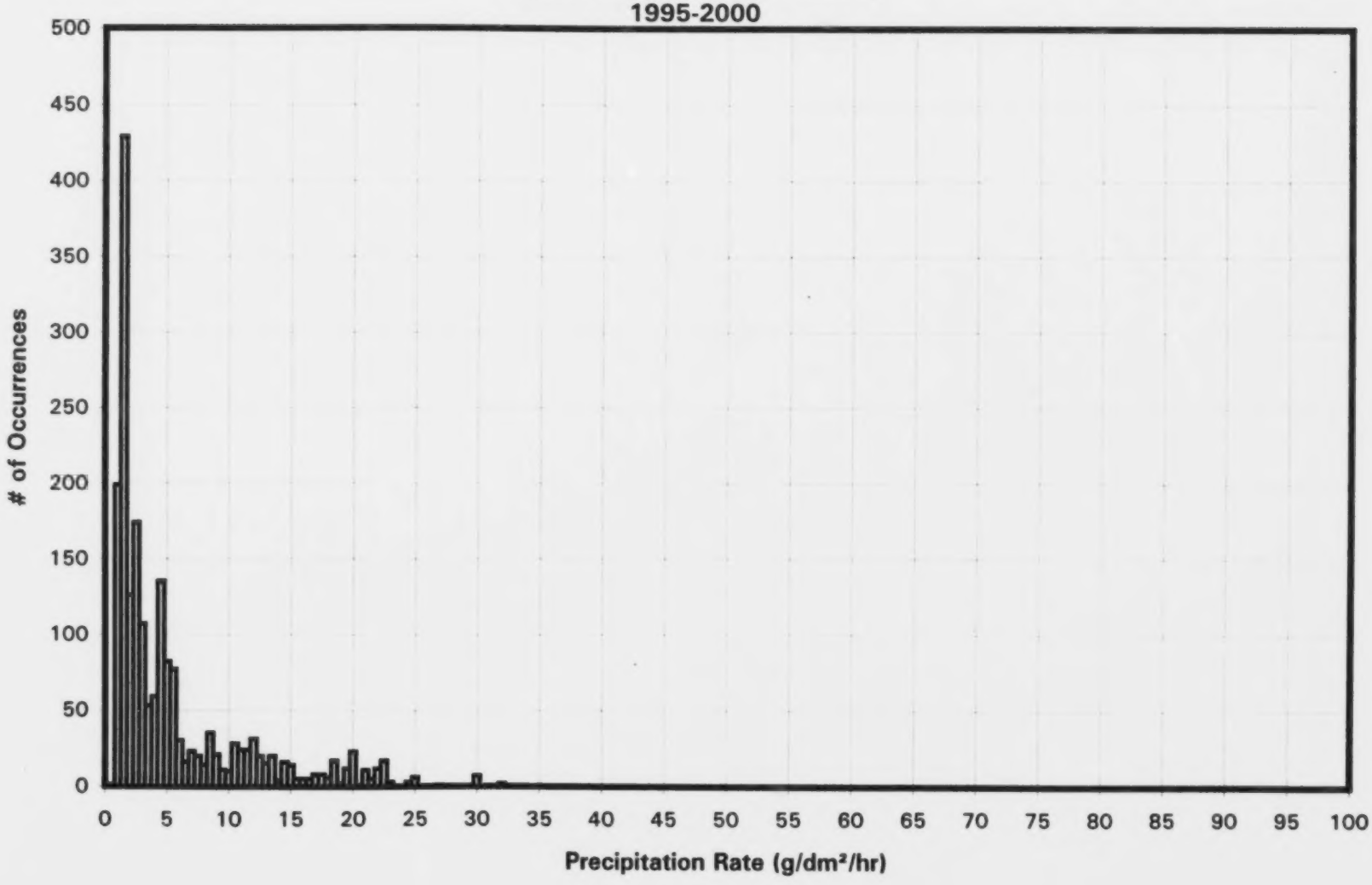
READAC AND CR21X ANALYSIS - NATURAL SNOW

-18 TO -22°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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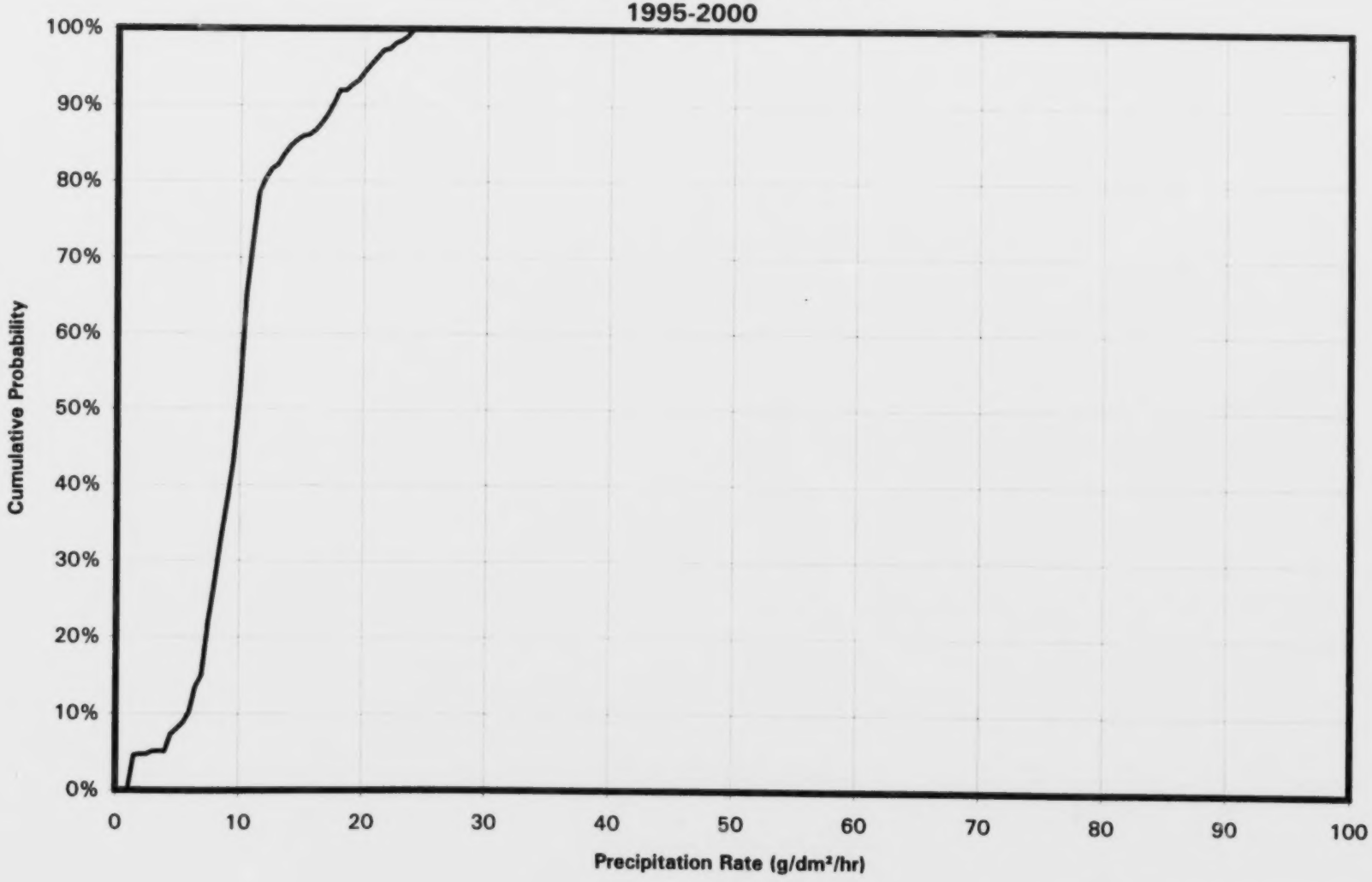
READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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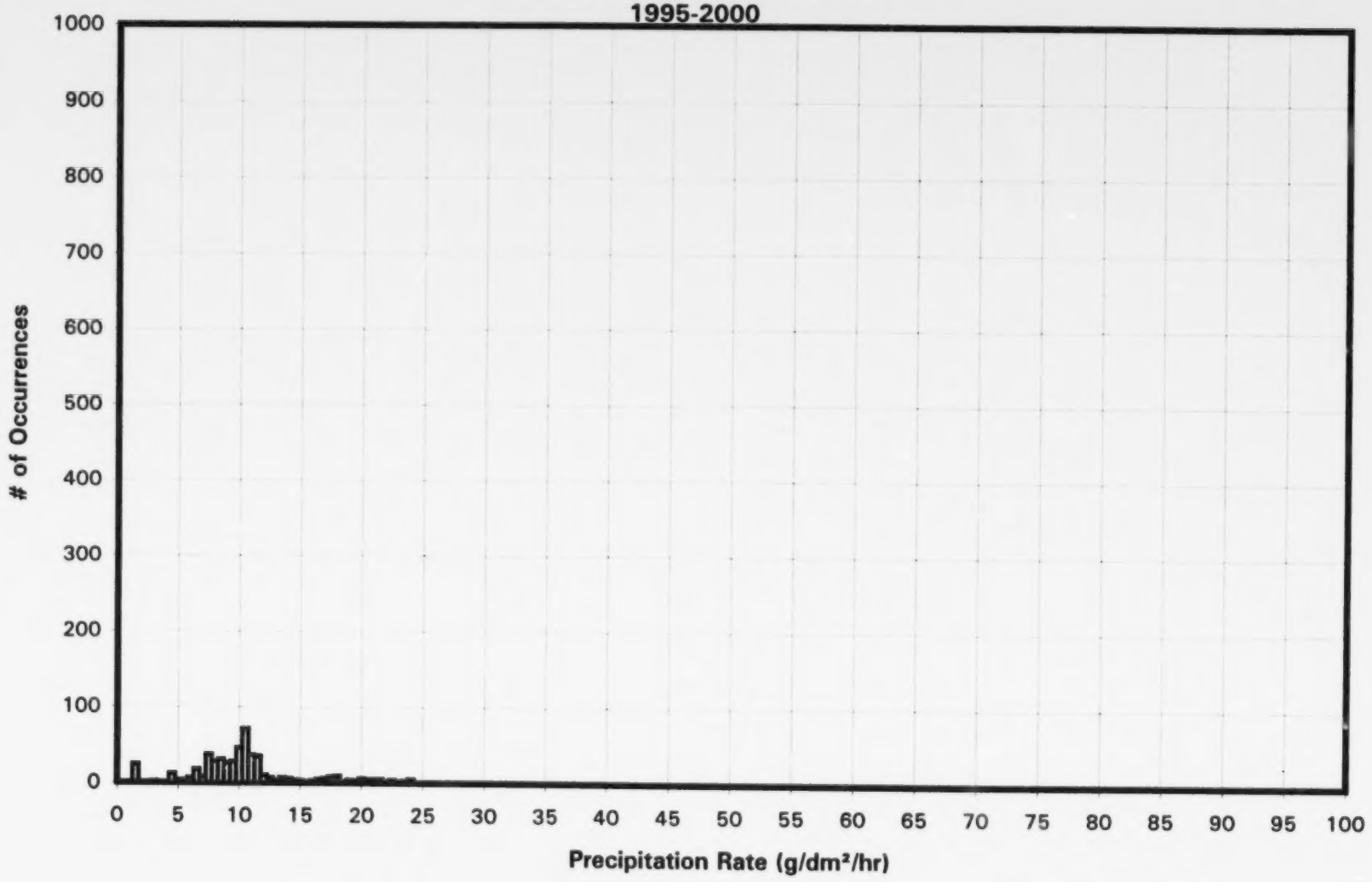
READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

35-MINUTE RATE EVERY MINUTE

1995-2000



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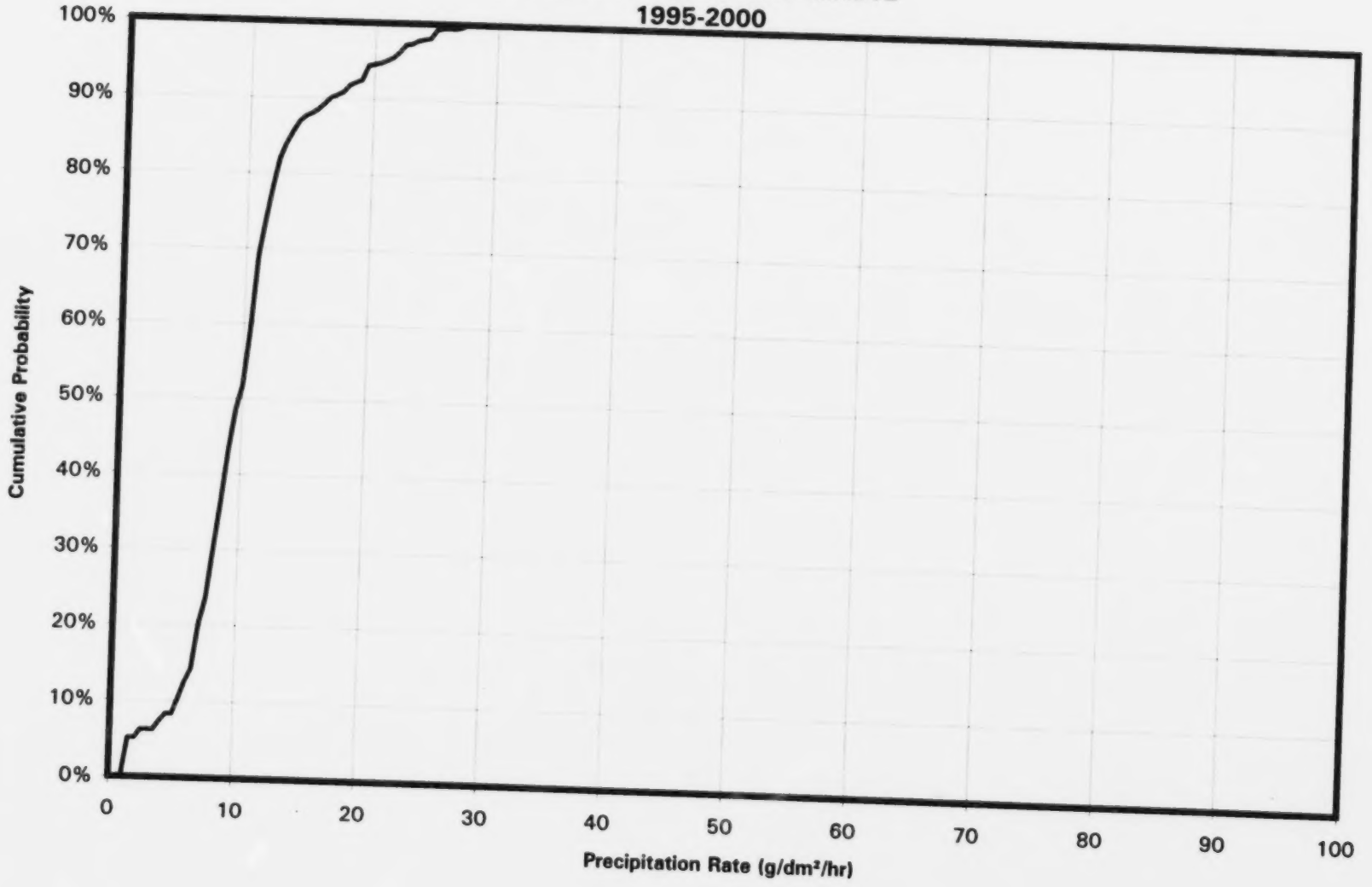
READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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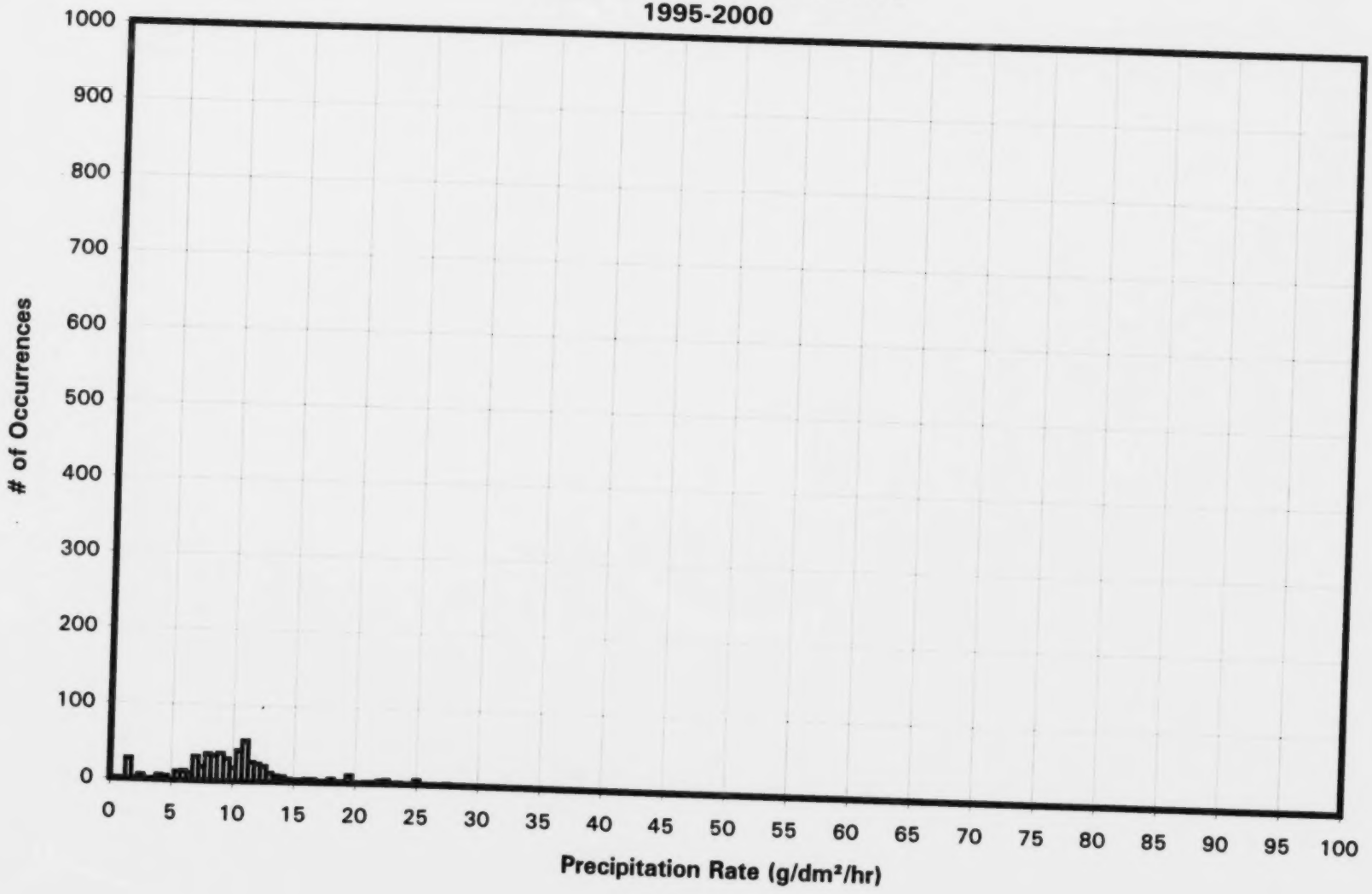
READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

20-MINUTE RATE EVERY MINUTE

1995-2000



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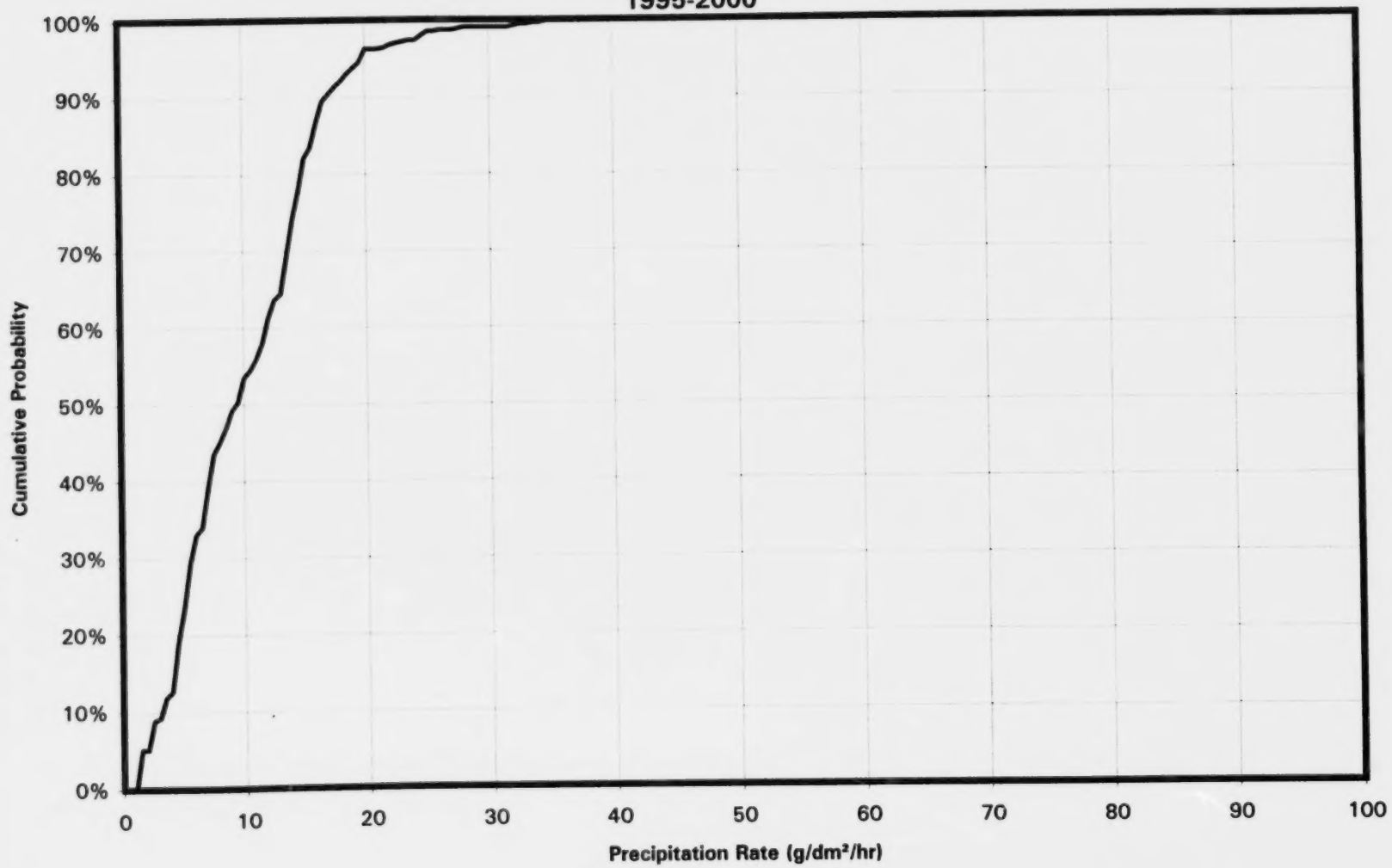
20/09/00, 11:09 AM

READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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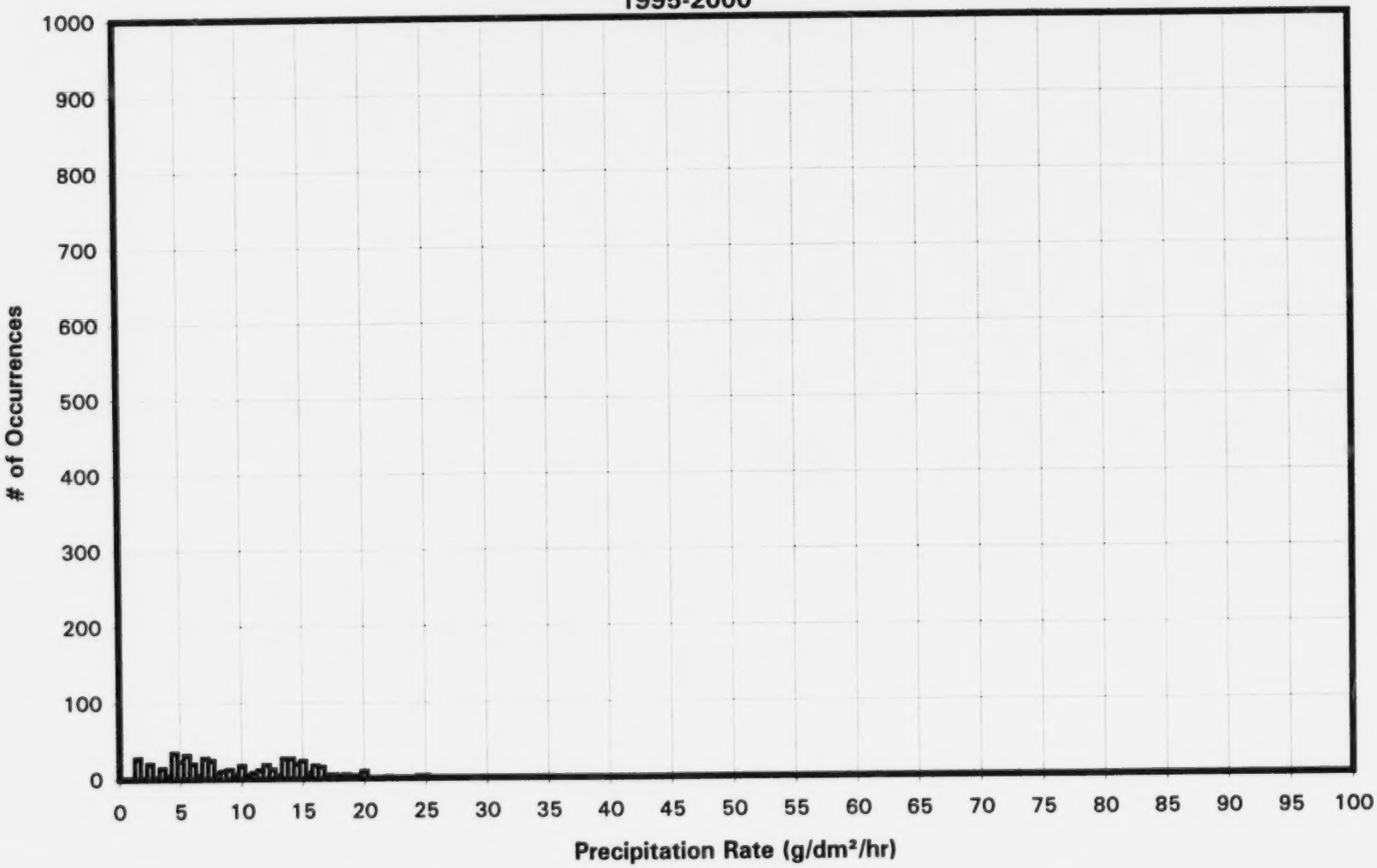
READAC AND CR21X ANALYSIS - NATURAL SNOW

-22 TO -25°C

6-MINUTE RATE EVERY MINUTE

1995-2000



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20/09/00, 11:26 AM

APPENDIX C

SNOW WEATHER DATA 1993-94 AND 1994-95

SNOW WEATHER DATA
1993-94 AND 1994-95

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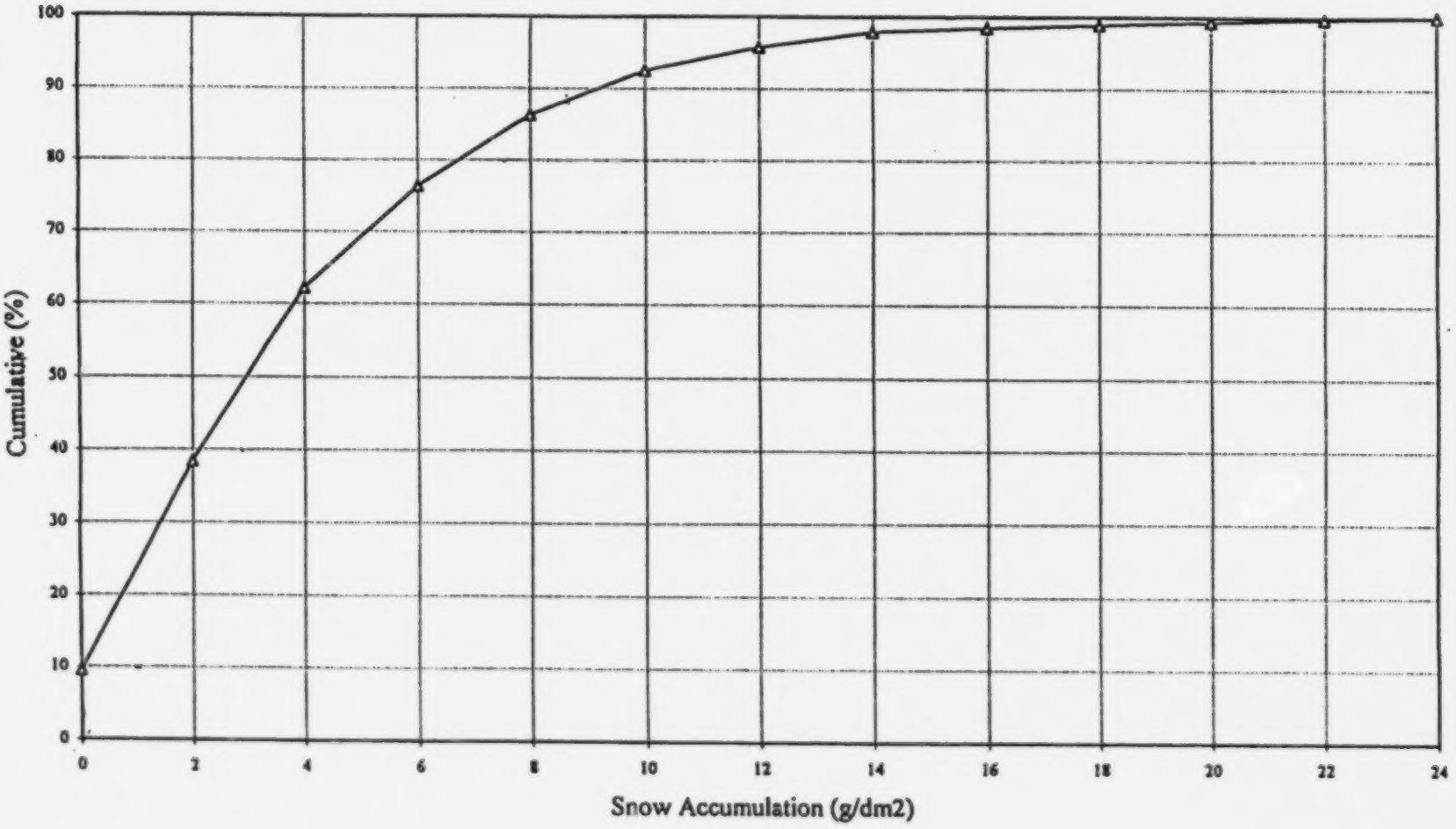
For 21 min. at Every 3 min.
For 1993-1994 Winter



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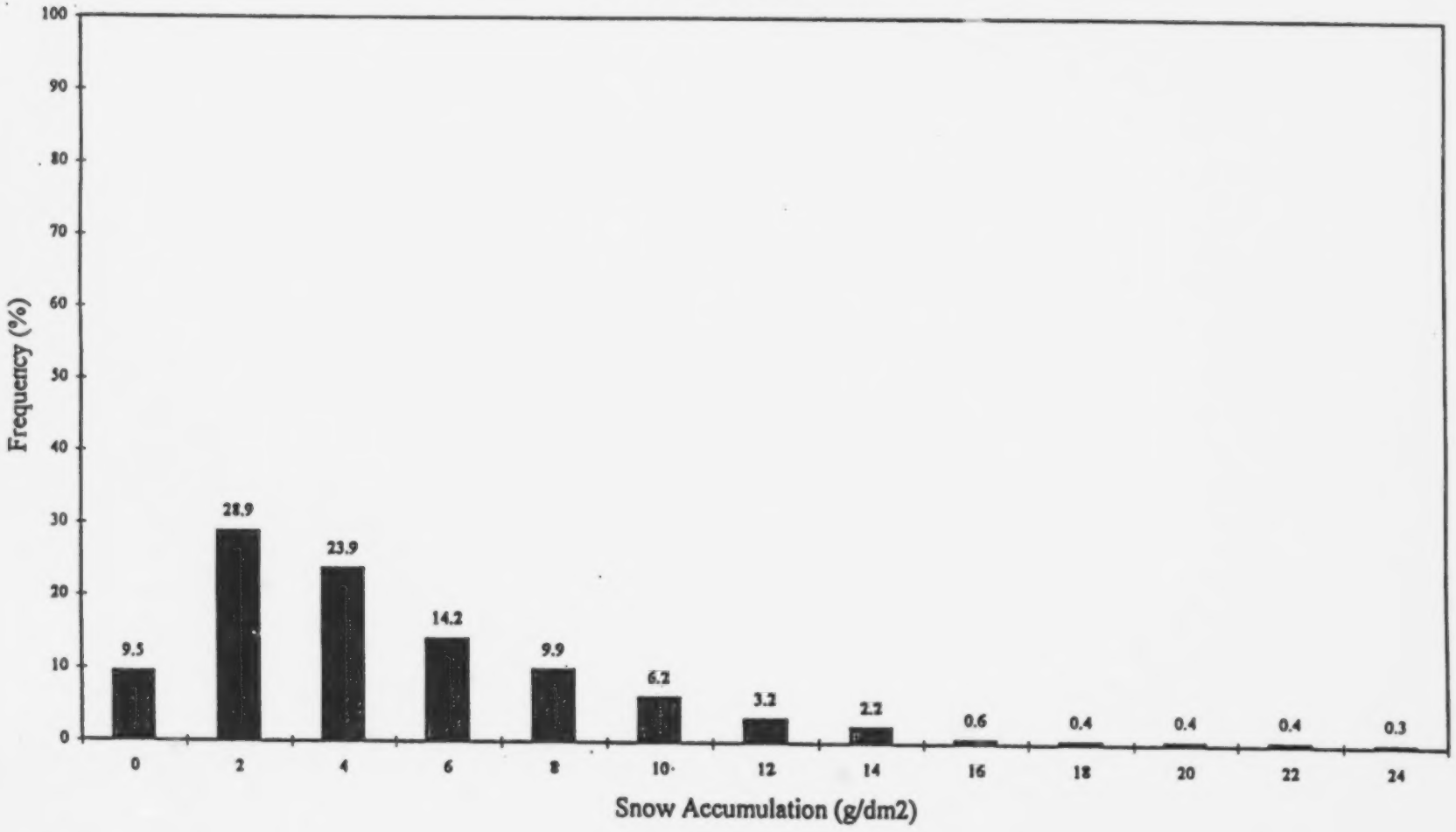
MHIST94.XLS

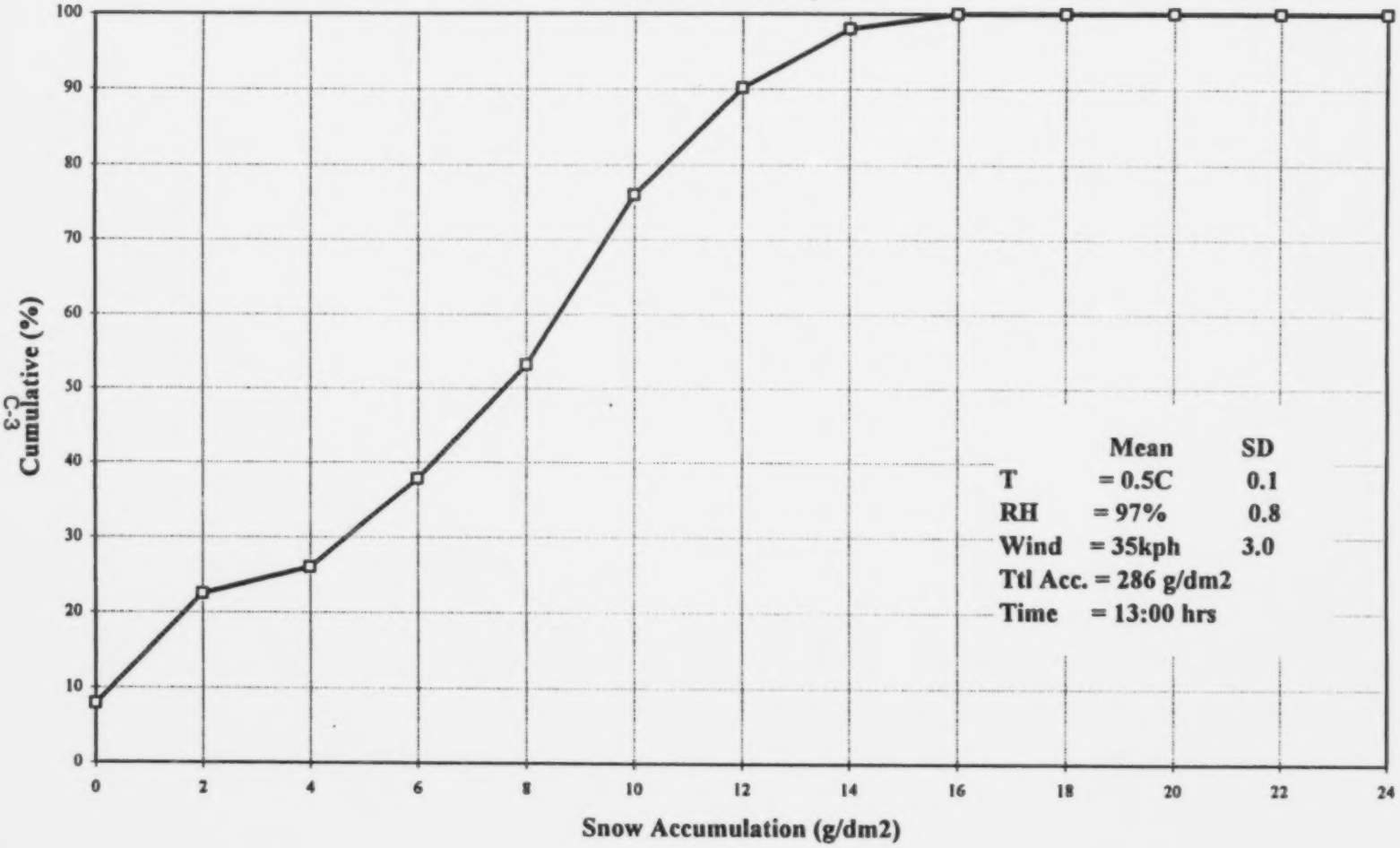
Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1993-1994 Winter



17/8/95 09:45

MHIST94.XL

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Dec. 21, 1993)



C-3

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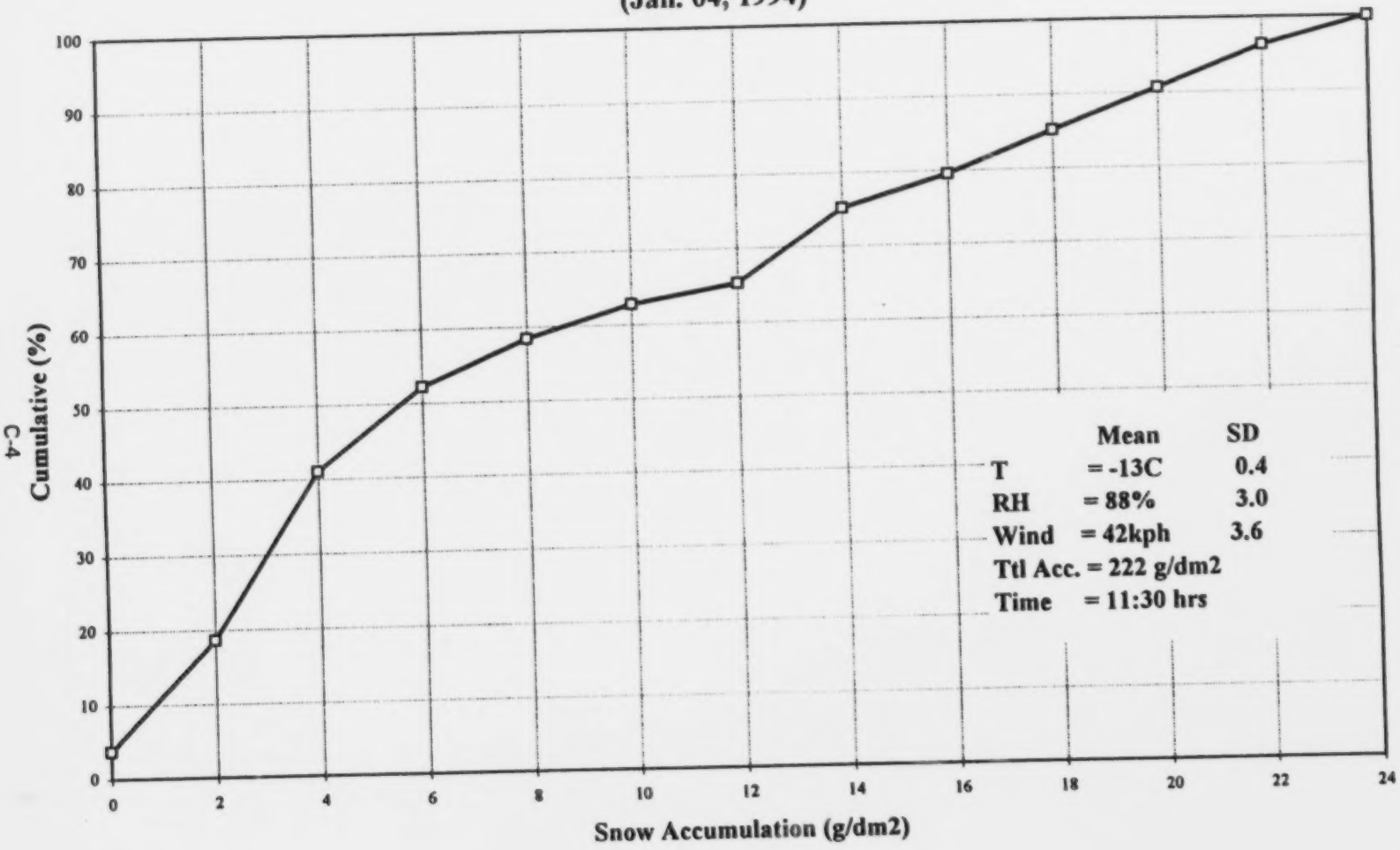
DEC2193.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 04, 1994)



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JAN0494.XLS

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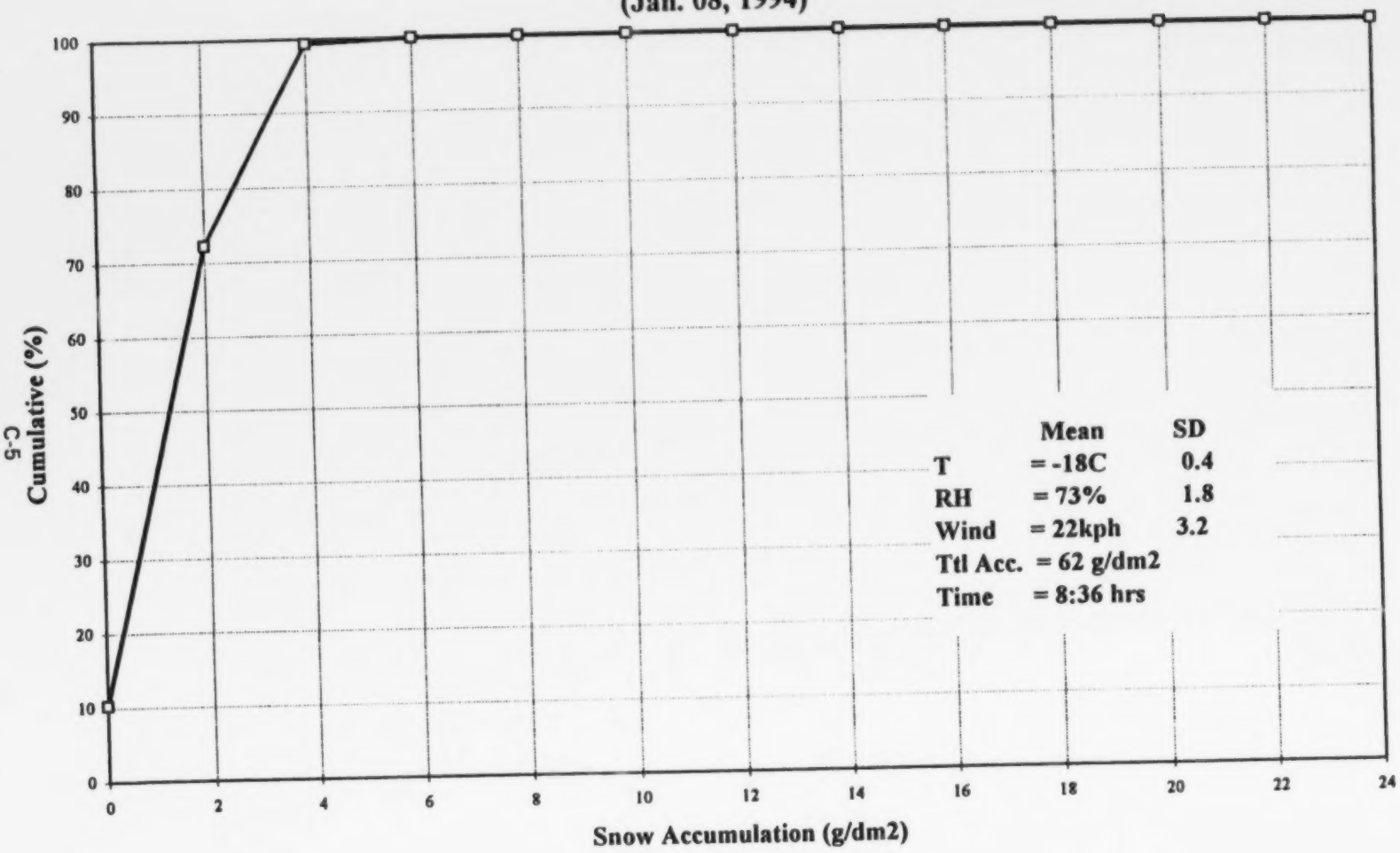
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 08, 1994)



C-5

JAN0894.XLS

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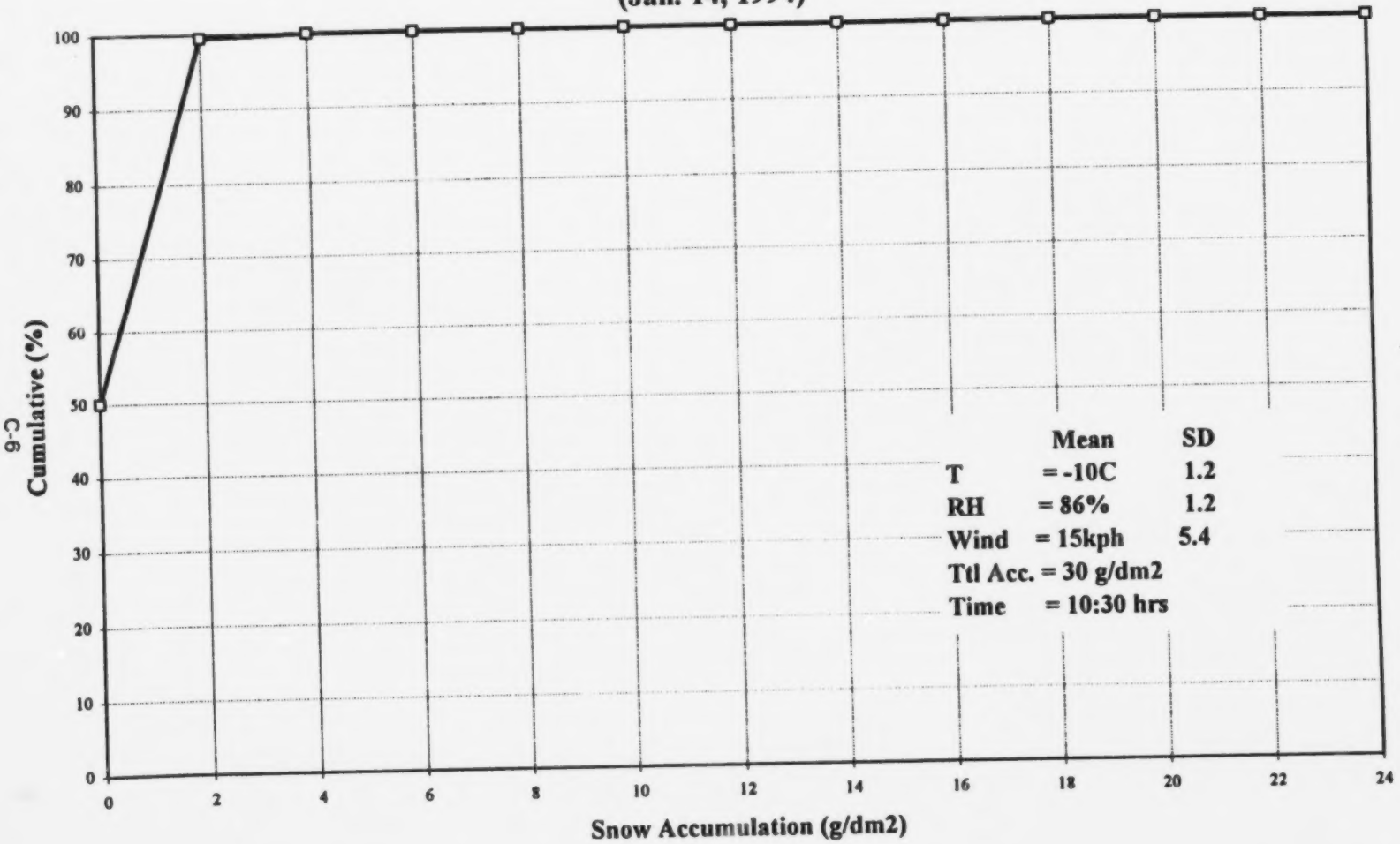
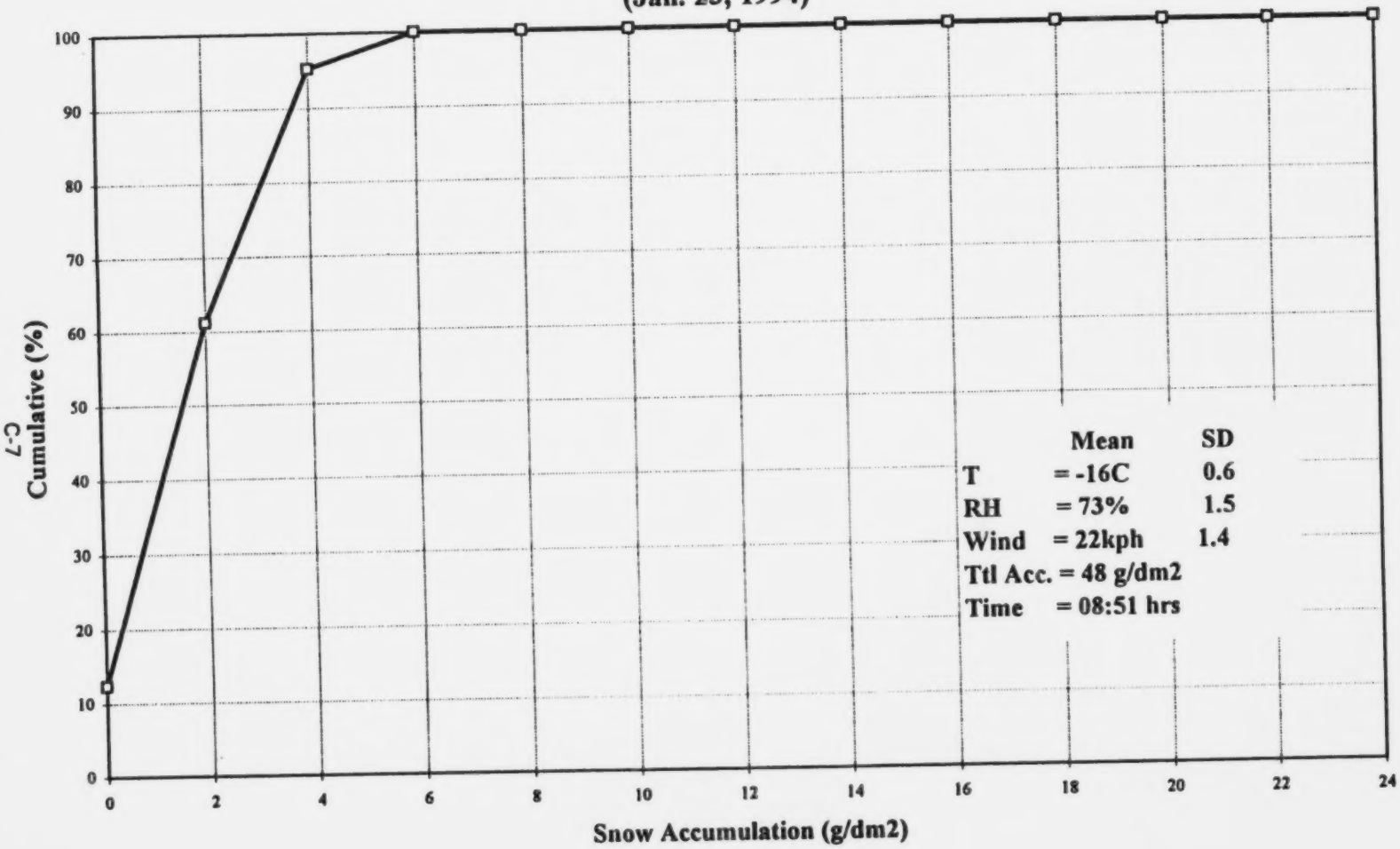
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 14, 1994)



JAN1494.XLS

18/8/95 16:22

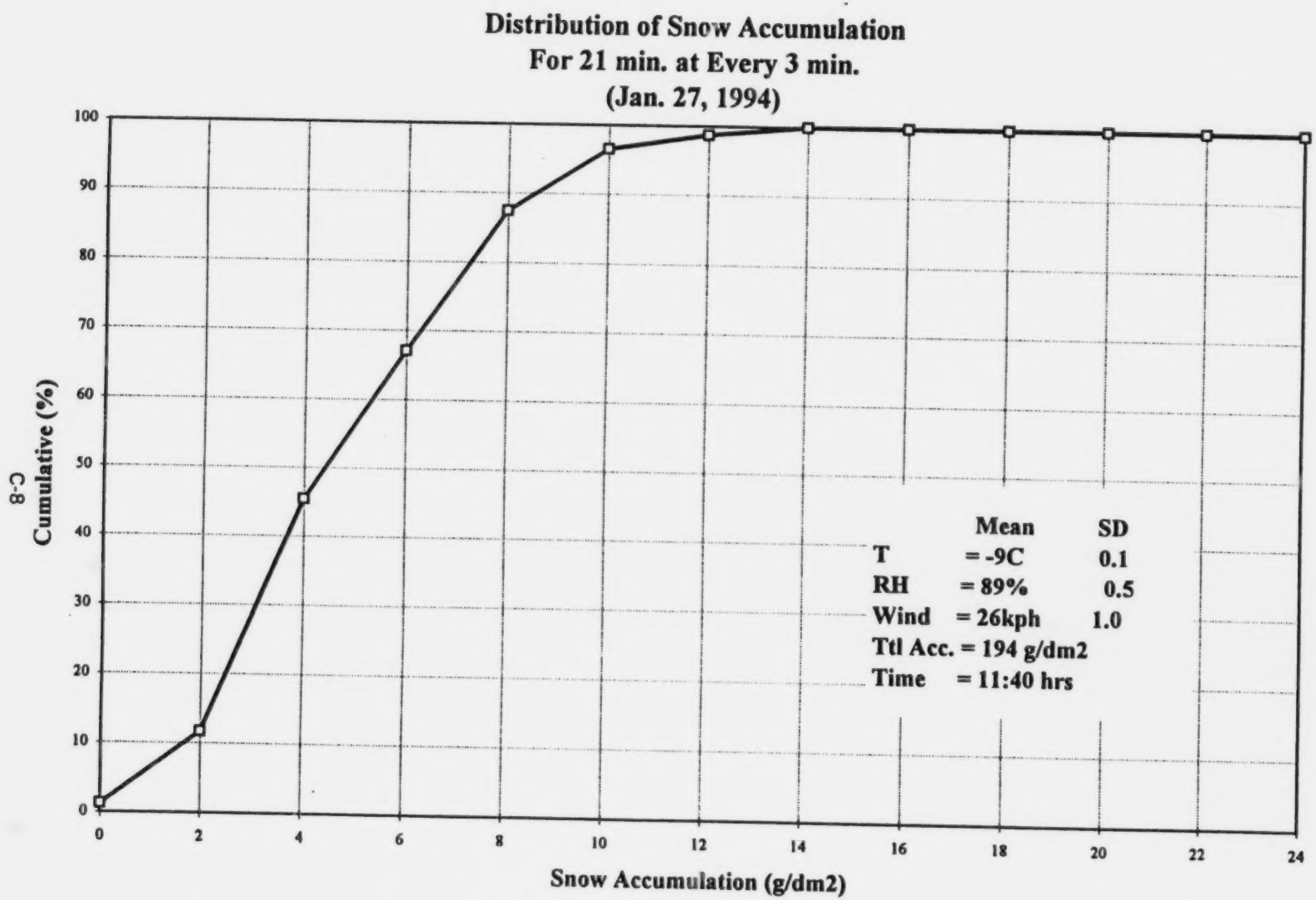
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 23, 1994)



C-7

17/8/95 16:00

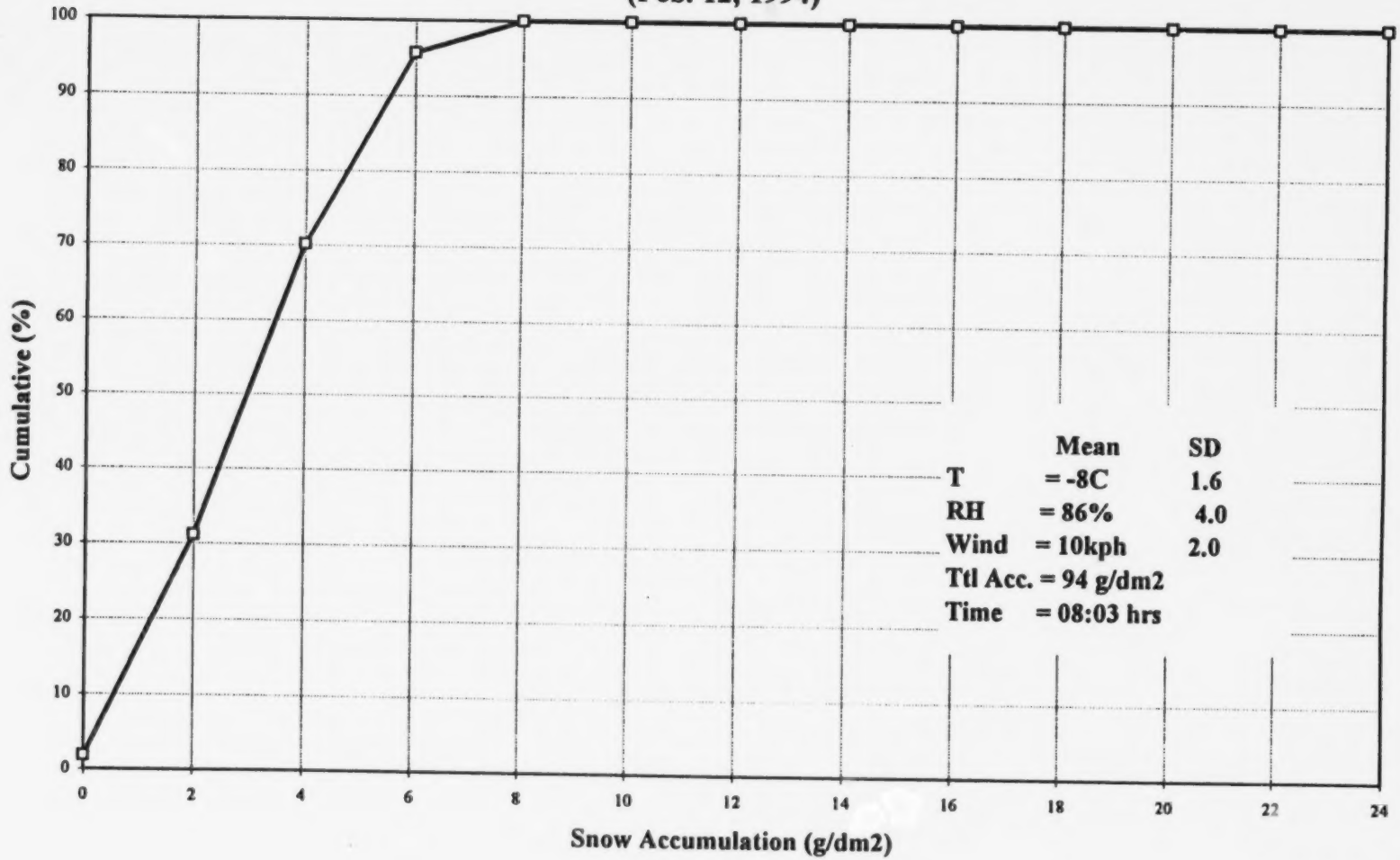
JAN2394.XLS



18/8/95 16:20

JAN2794.XLS

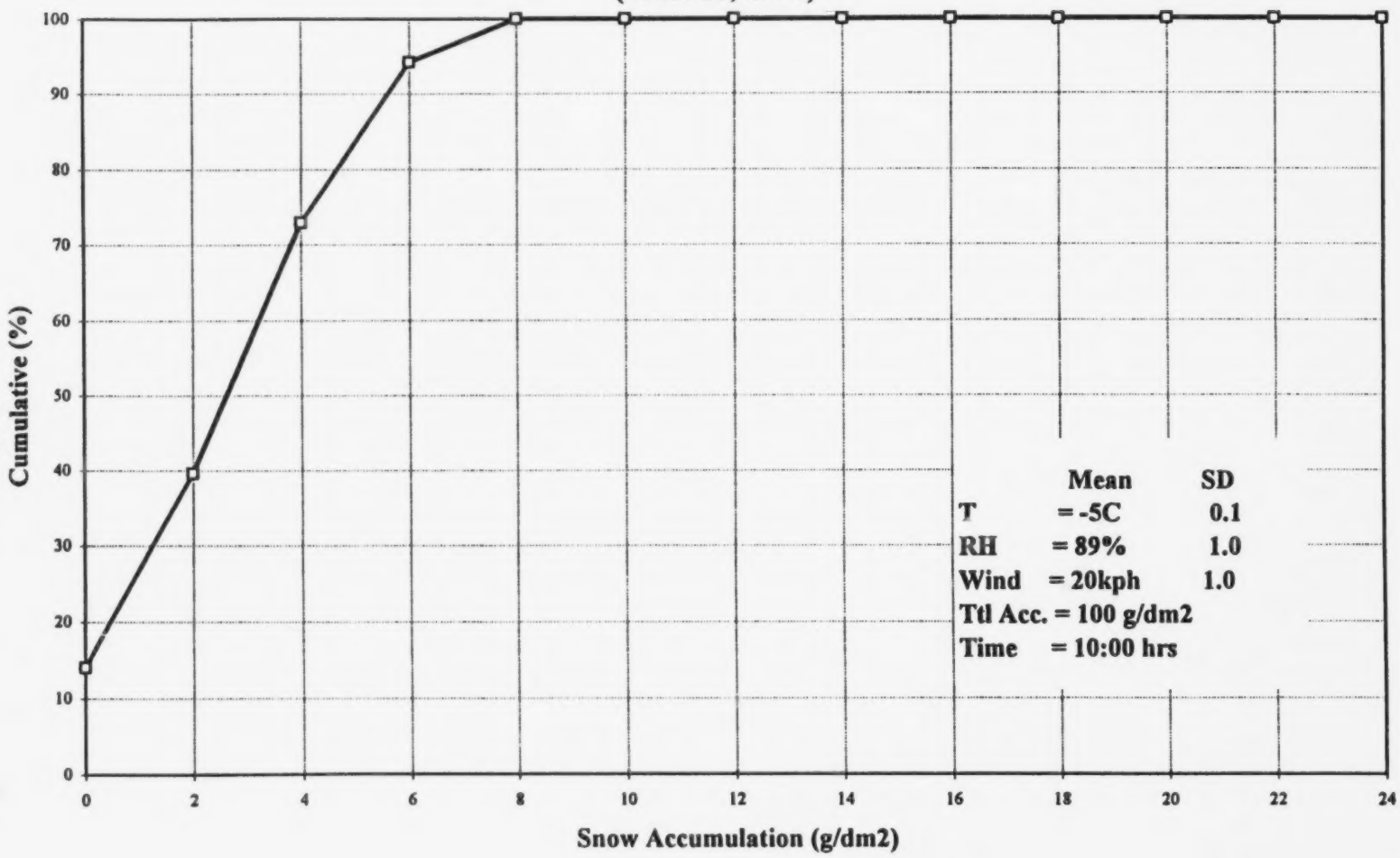
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 12, 1994)



16/8/95 15:19

FEB1294.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 10, 1994)

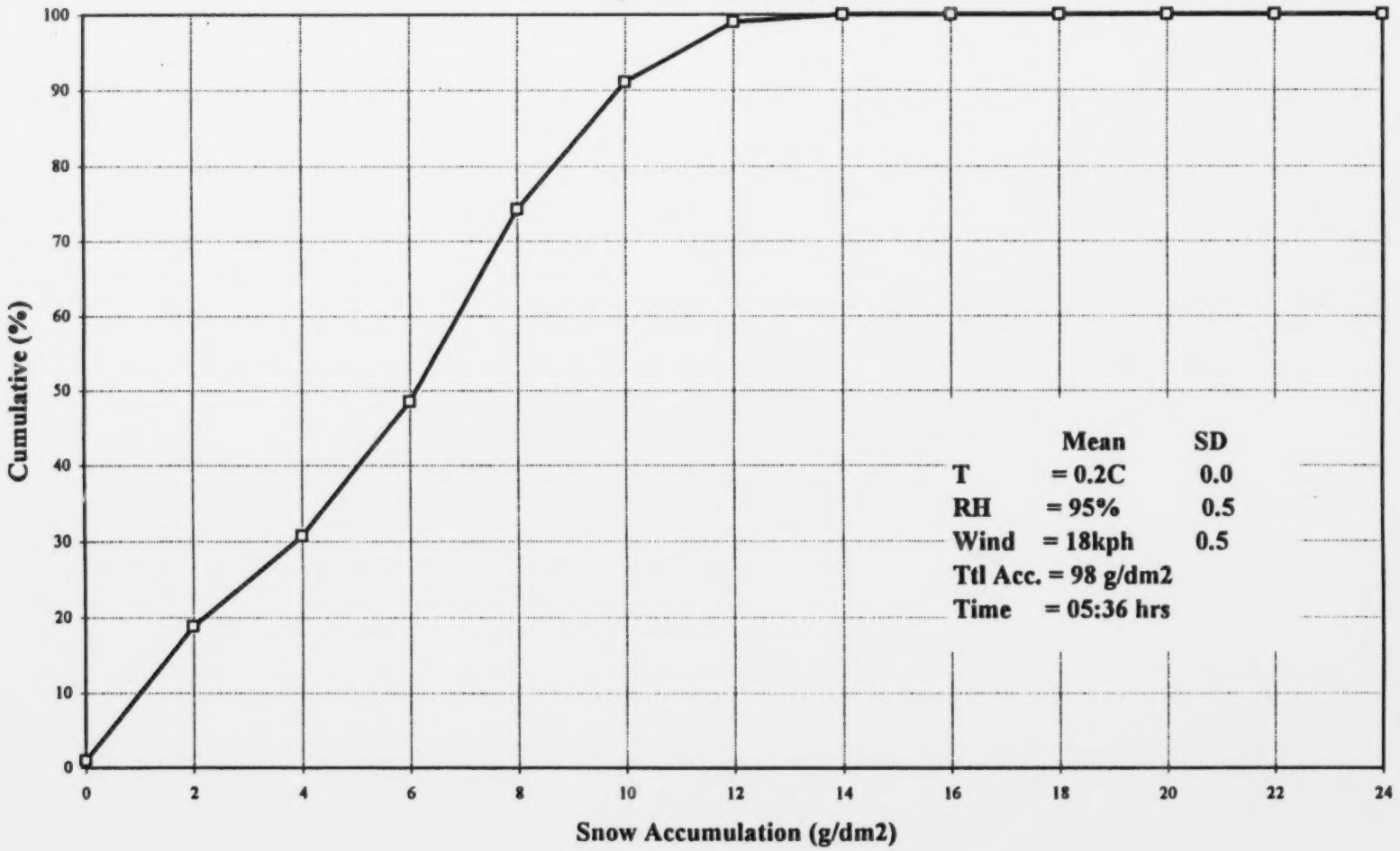


C-10

16/8/95 14:59

MAR1094.XLS

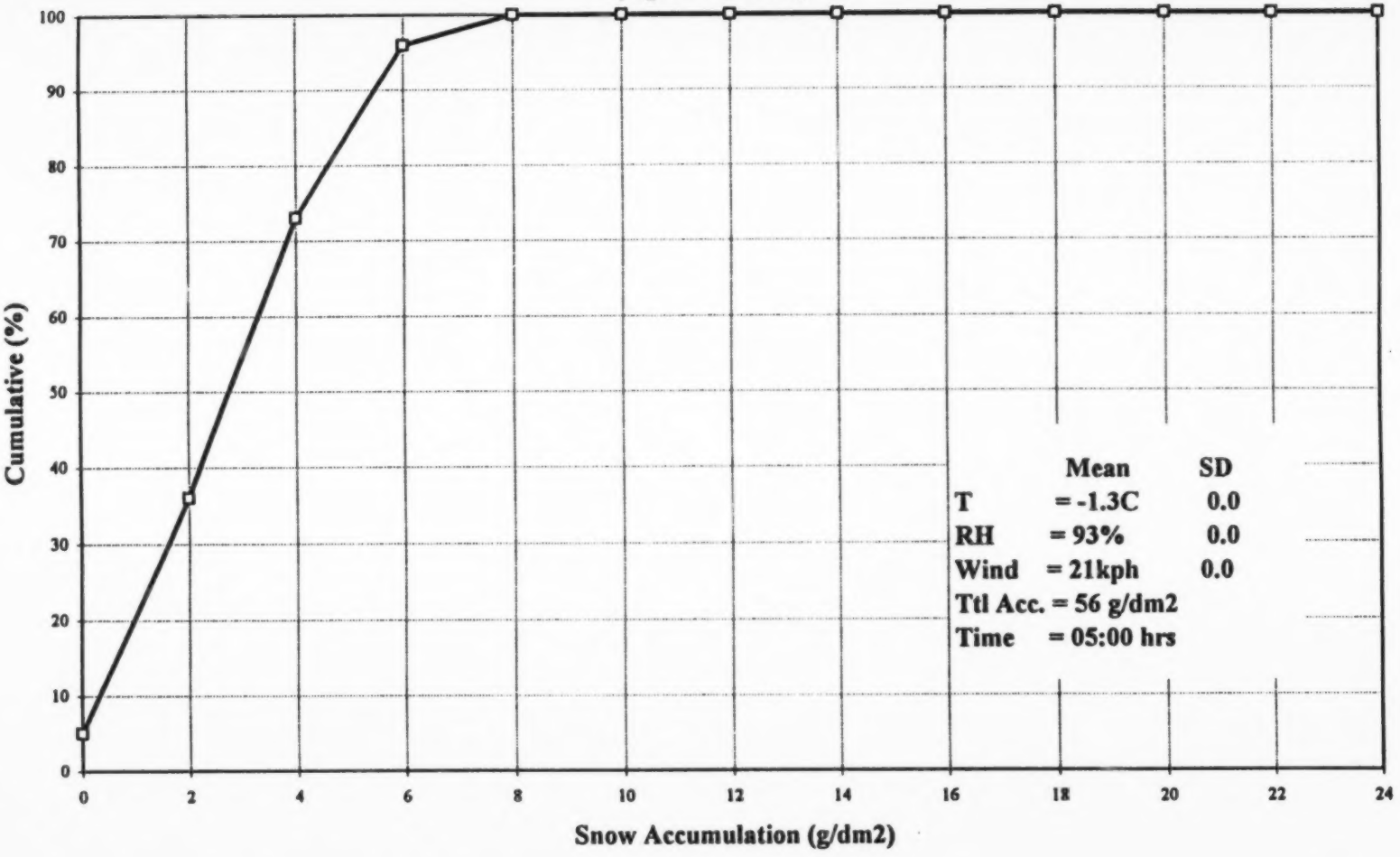
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 27, 1994)



18/8/95 16:30

MAR2794.XLS

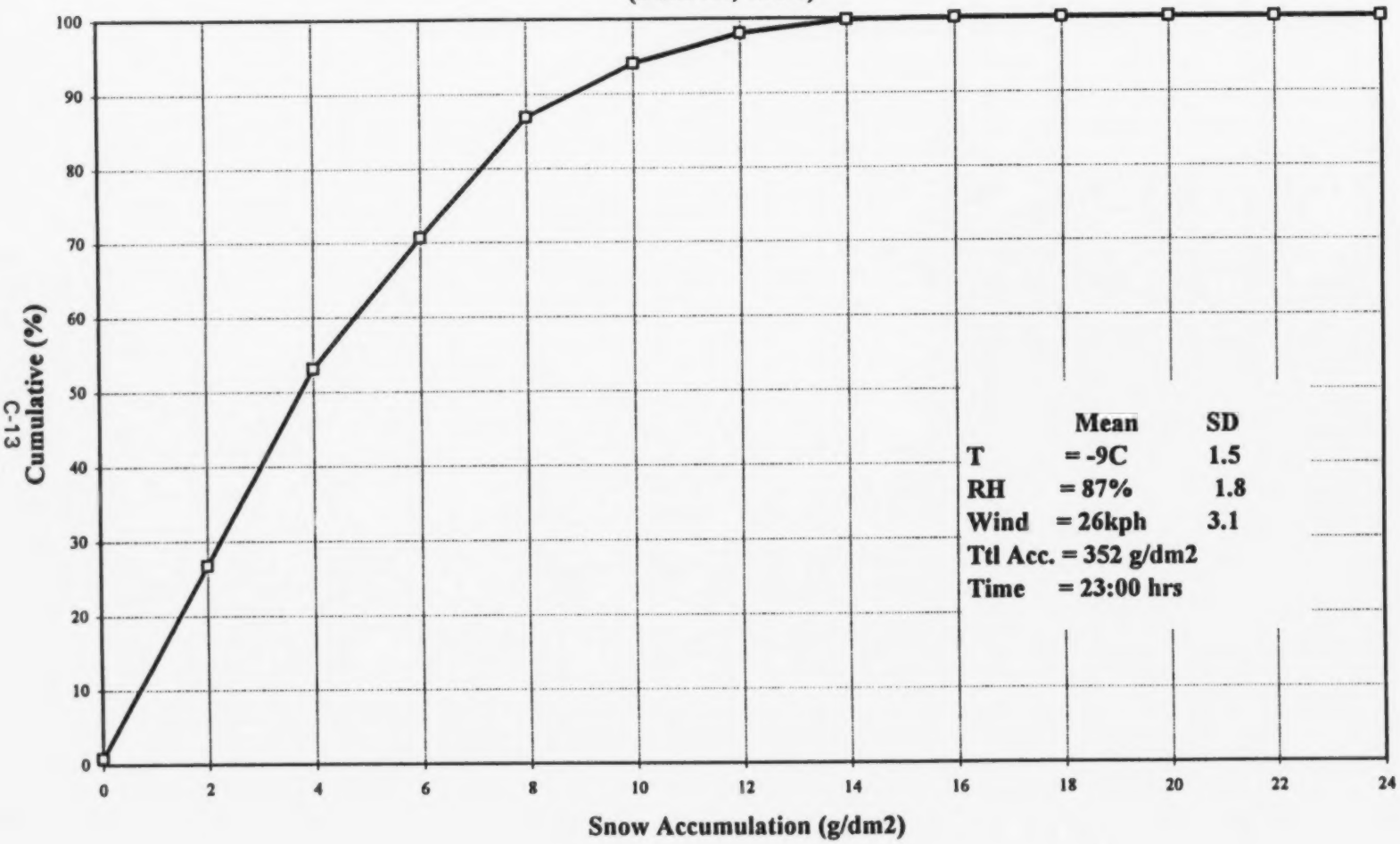
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Apr. 07, 1994)



17/8/95 16:37

APR0794.XLS

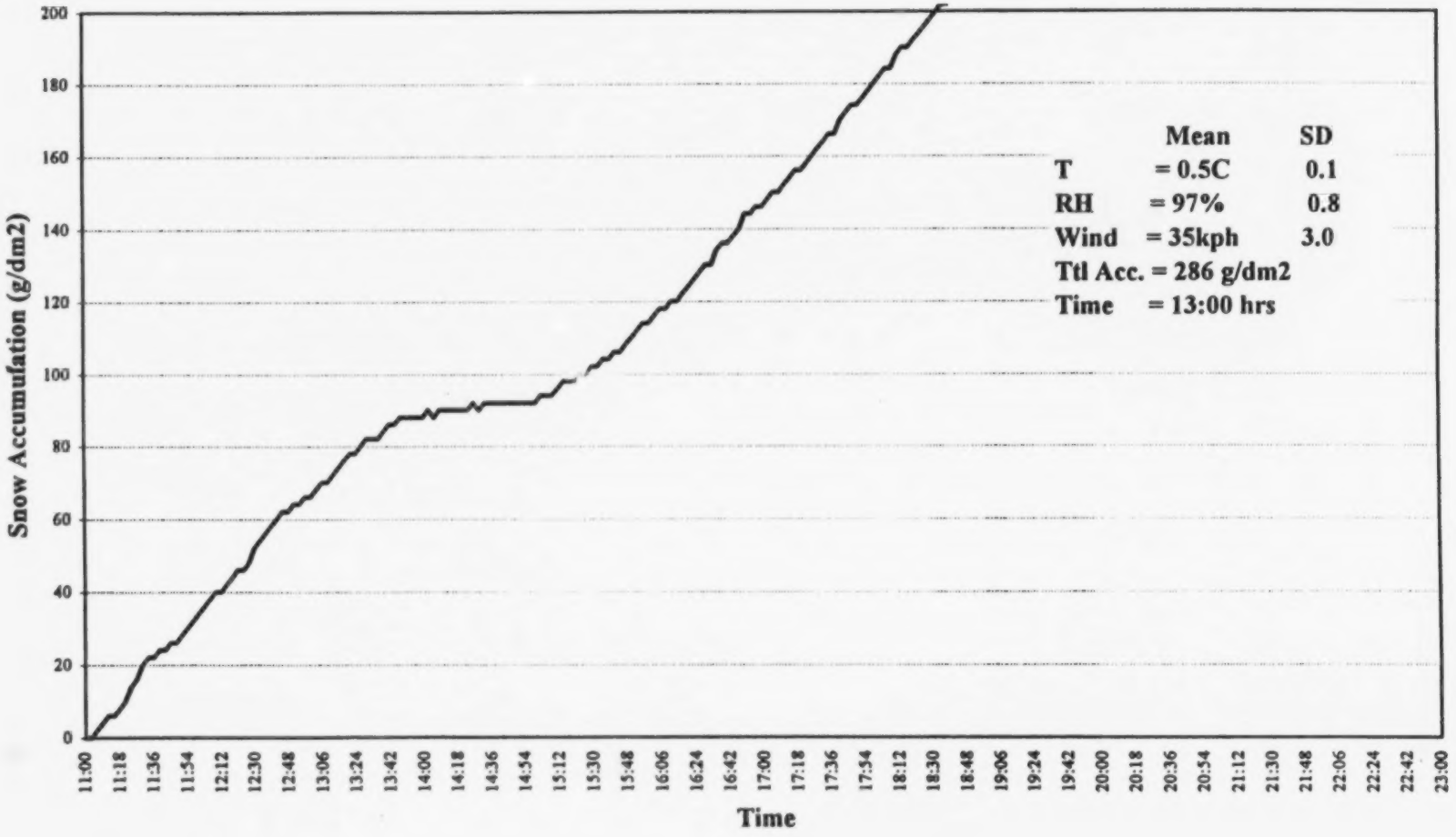
Distribution for Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 23, 1994)



16/8/95 15:21

FEB2394.XLS

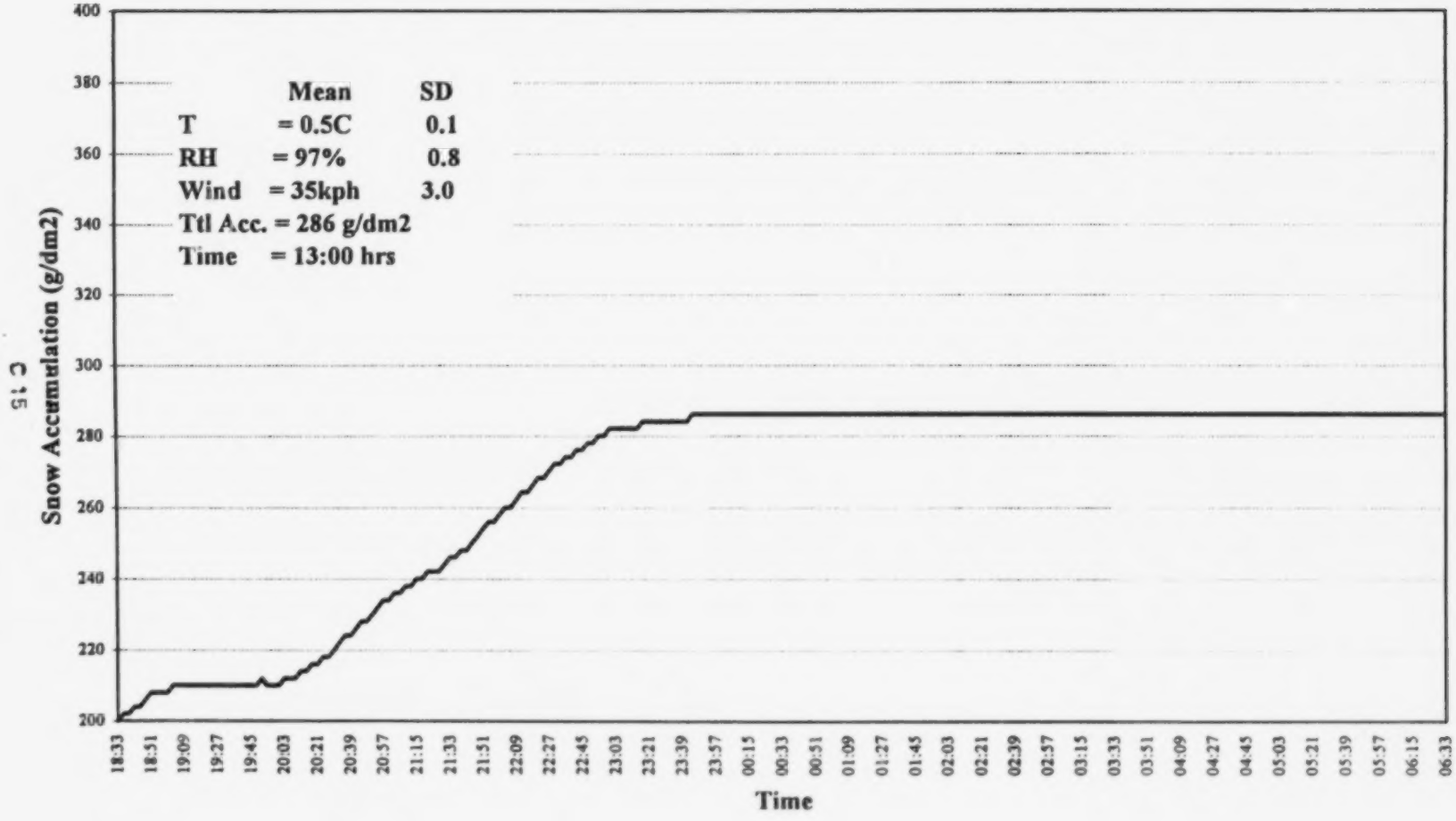
Total Snow Accumulation
for Dec. 21, 1993



14/8/95 15:04

DEC2193.XLS

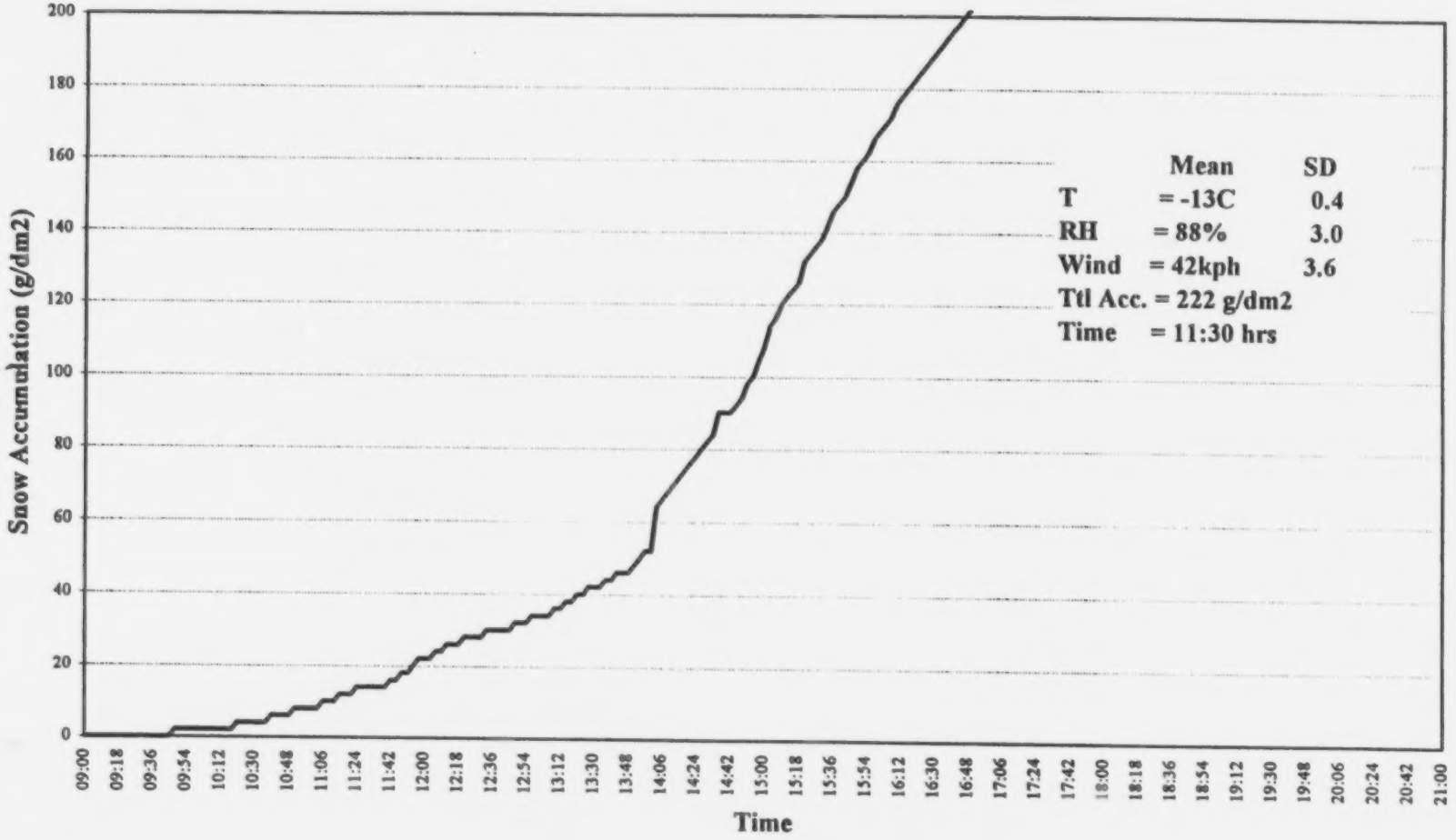
Total Snow Accumulation
for Dec. 21, 1993



14/8/95 15:04

DEC2193.XLS

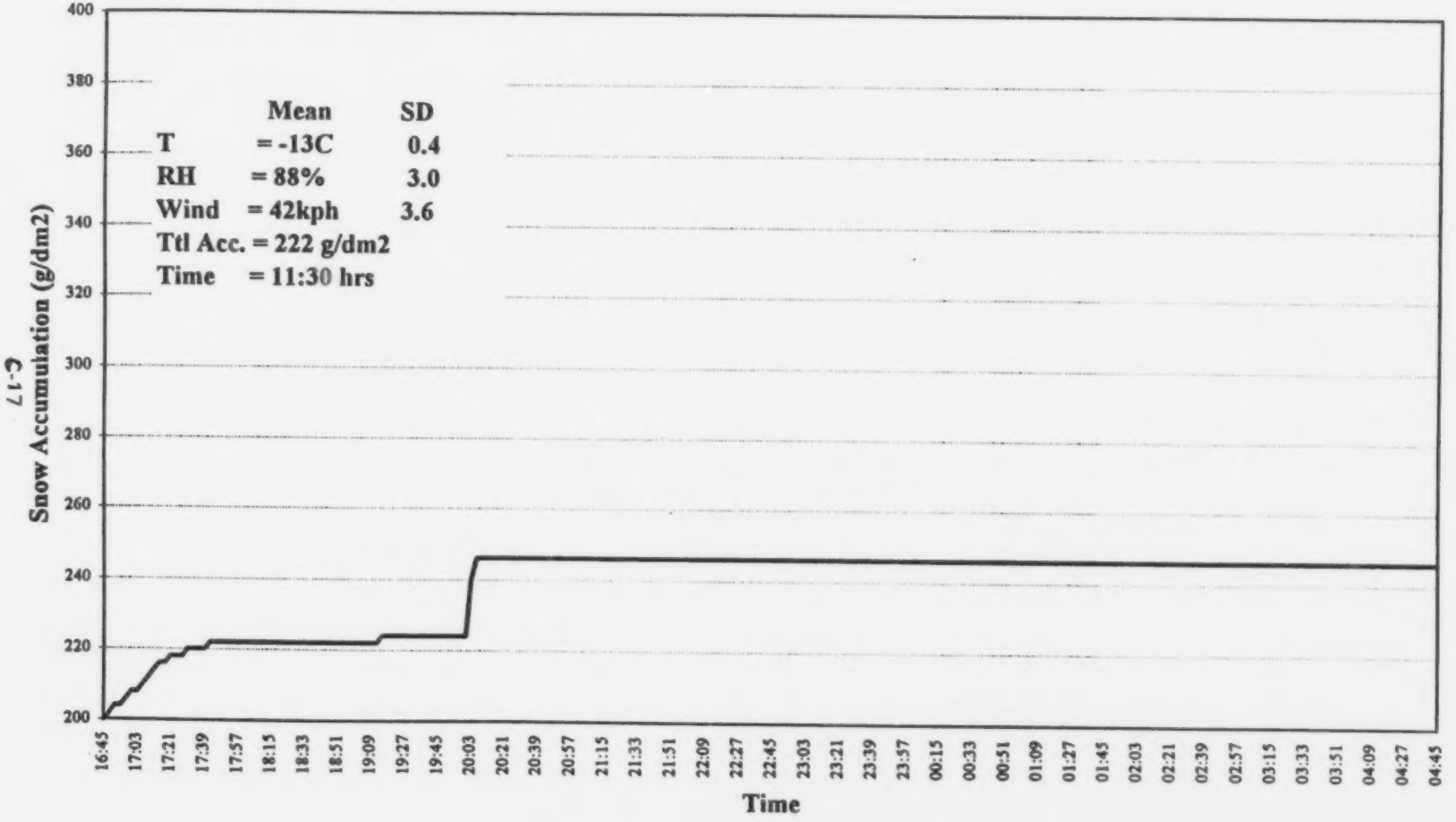
Total Snow Accumulation
for Jan 04, 1994



14/8/95 15:29

JAN0494.XLS

Total Snow Accumulation
for Jan 04, 1994

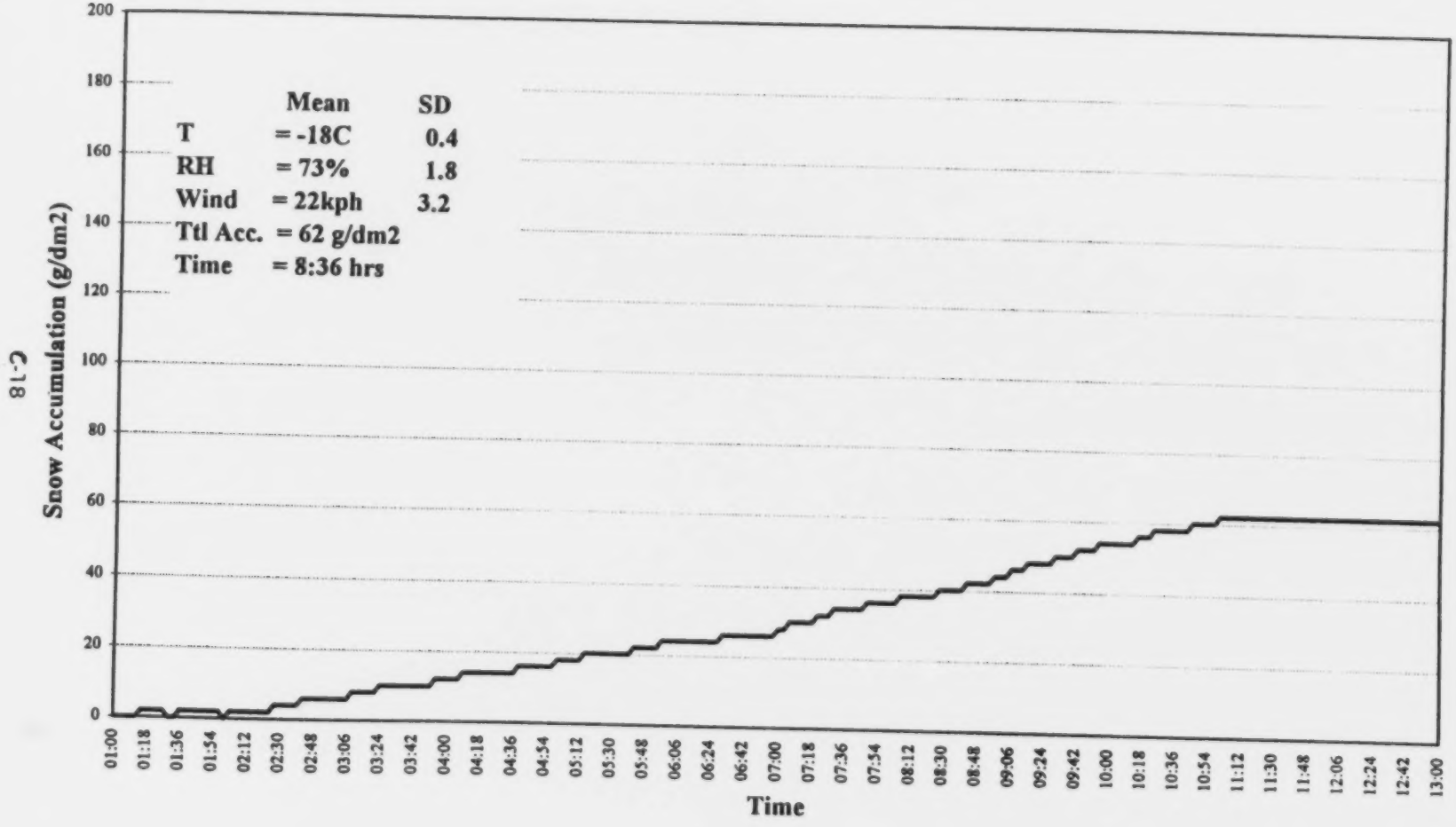


C-17

14/8/95 15:28

JAN0494.XLS

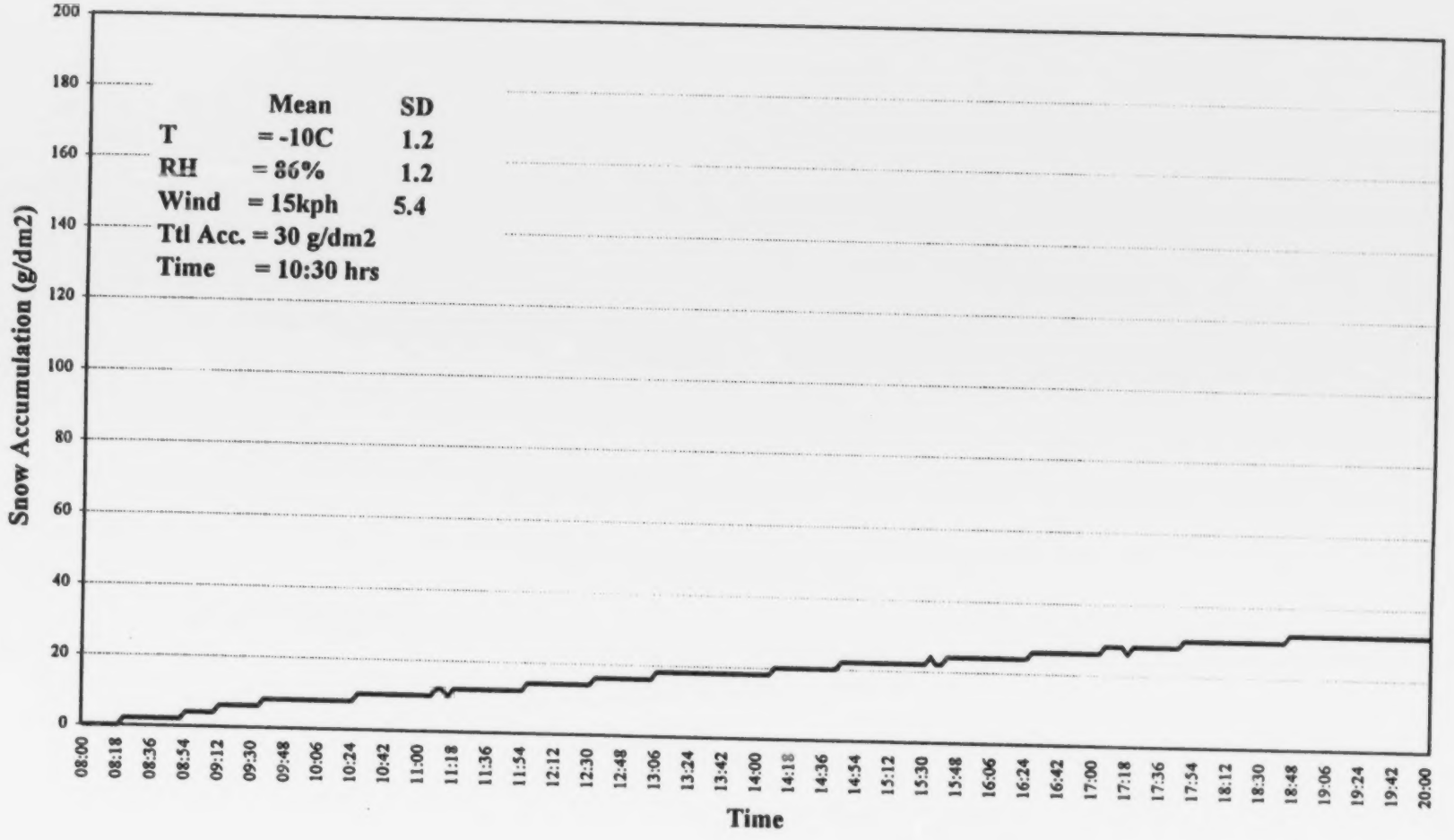
Total Snow Accumulation
for Jan. 08, 1994



14/8/95 15:23

JAN0894.XLS

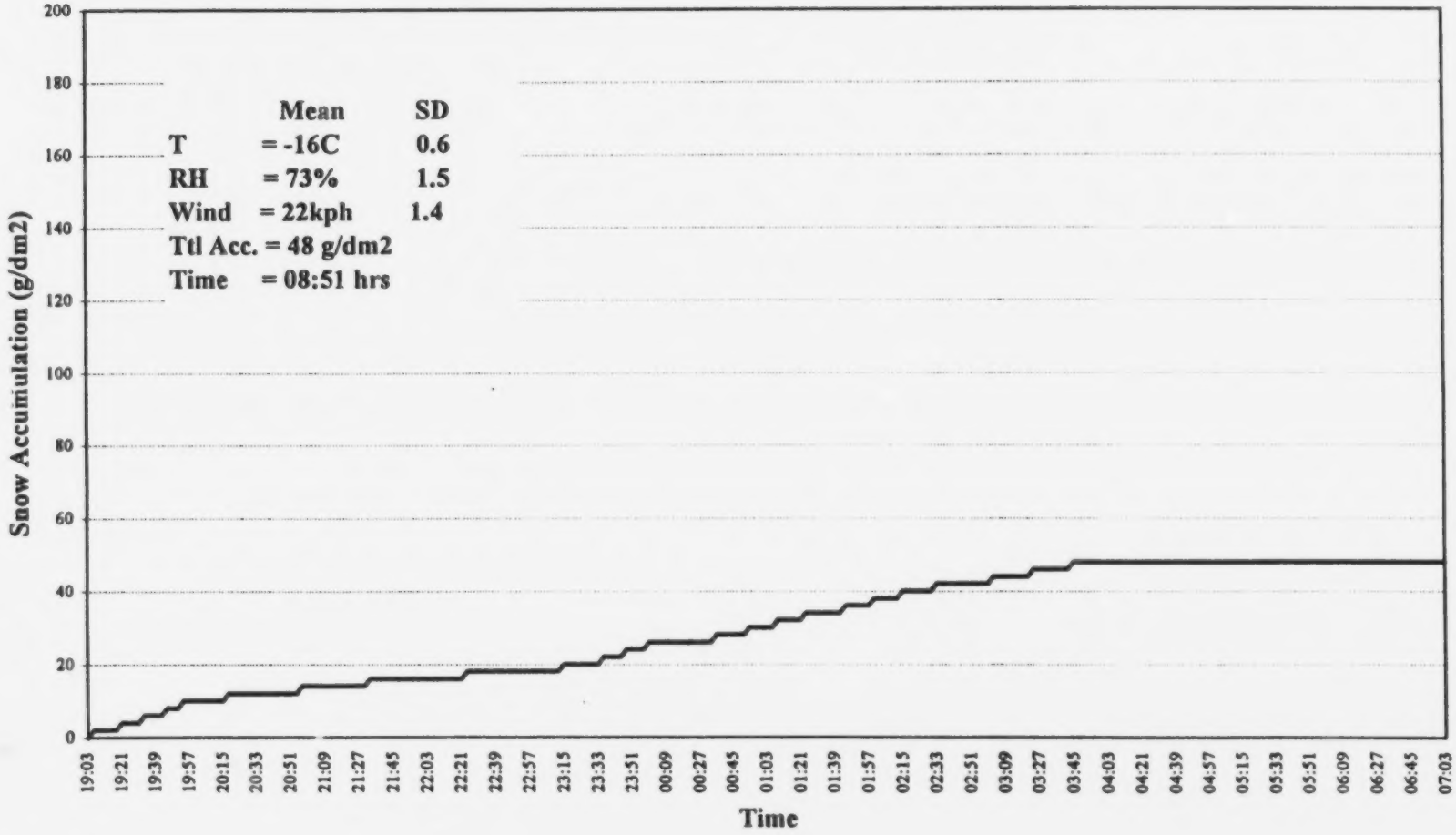
Total Snow Accumulation
for Jan 14, 1994



14/8/95 15:44

JAN1494.XLS

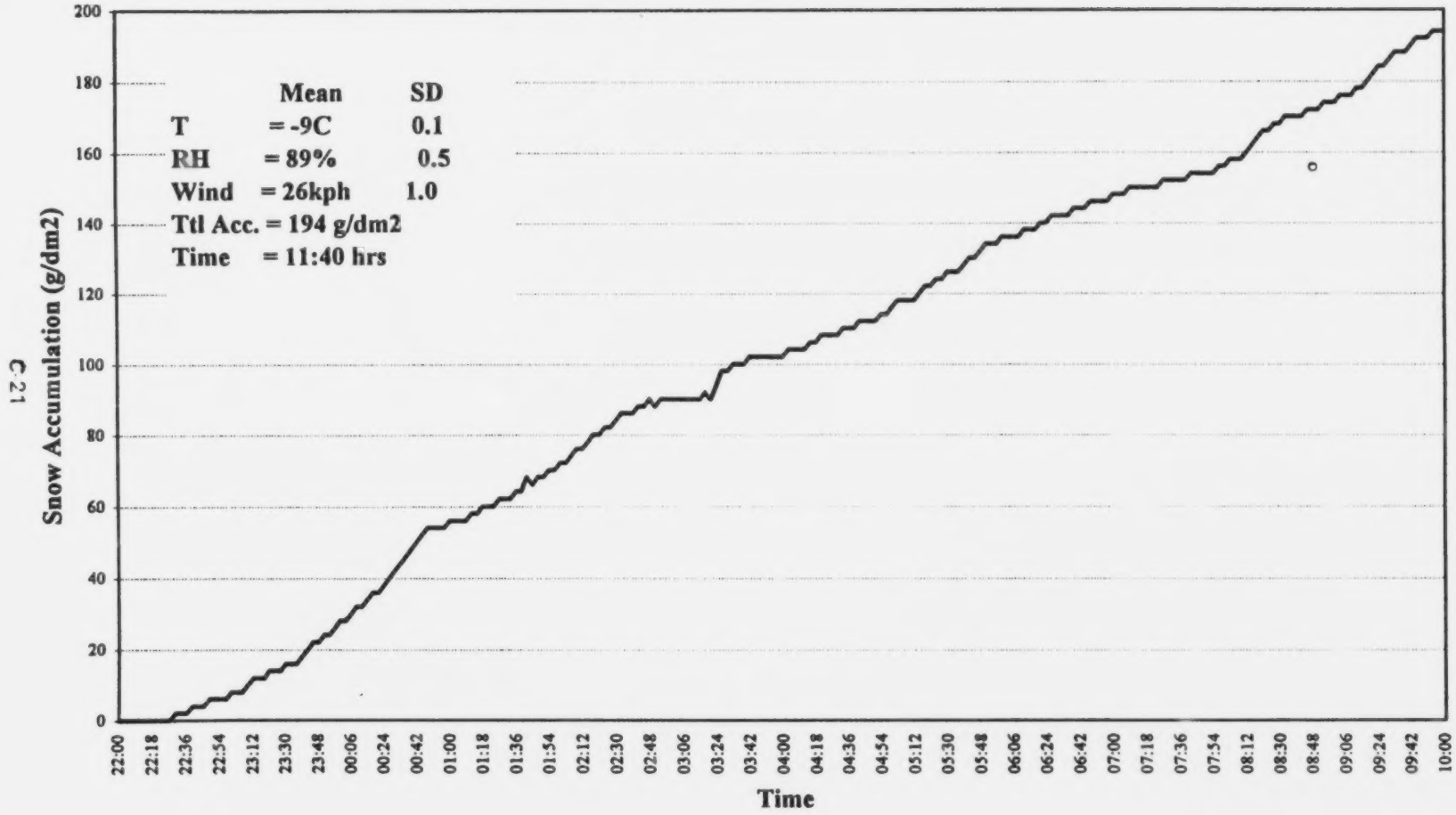
Total Snow Accumulation
for Jan. 23, 1994



14/8/95 15:25

JAN2394.XLS

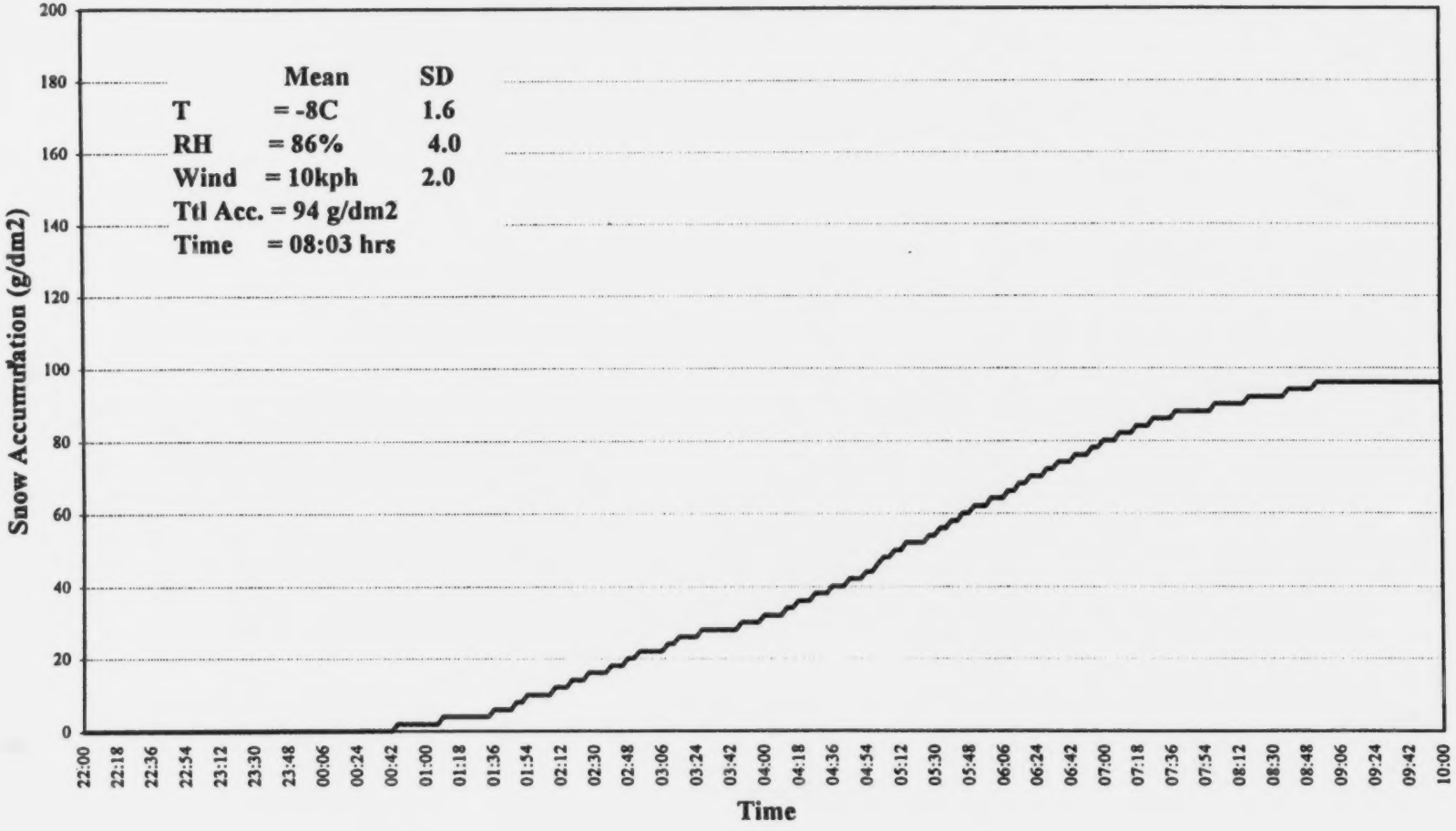
Total Snow Accumulation
for Jan. 27, 1993



14/8/95 15:26

JAN2794.XLS

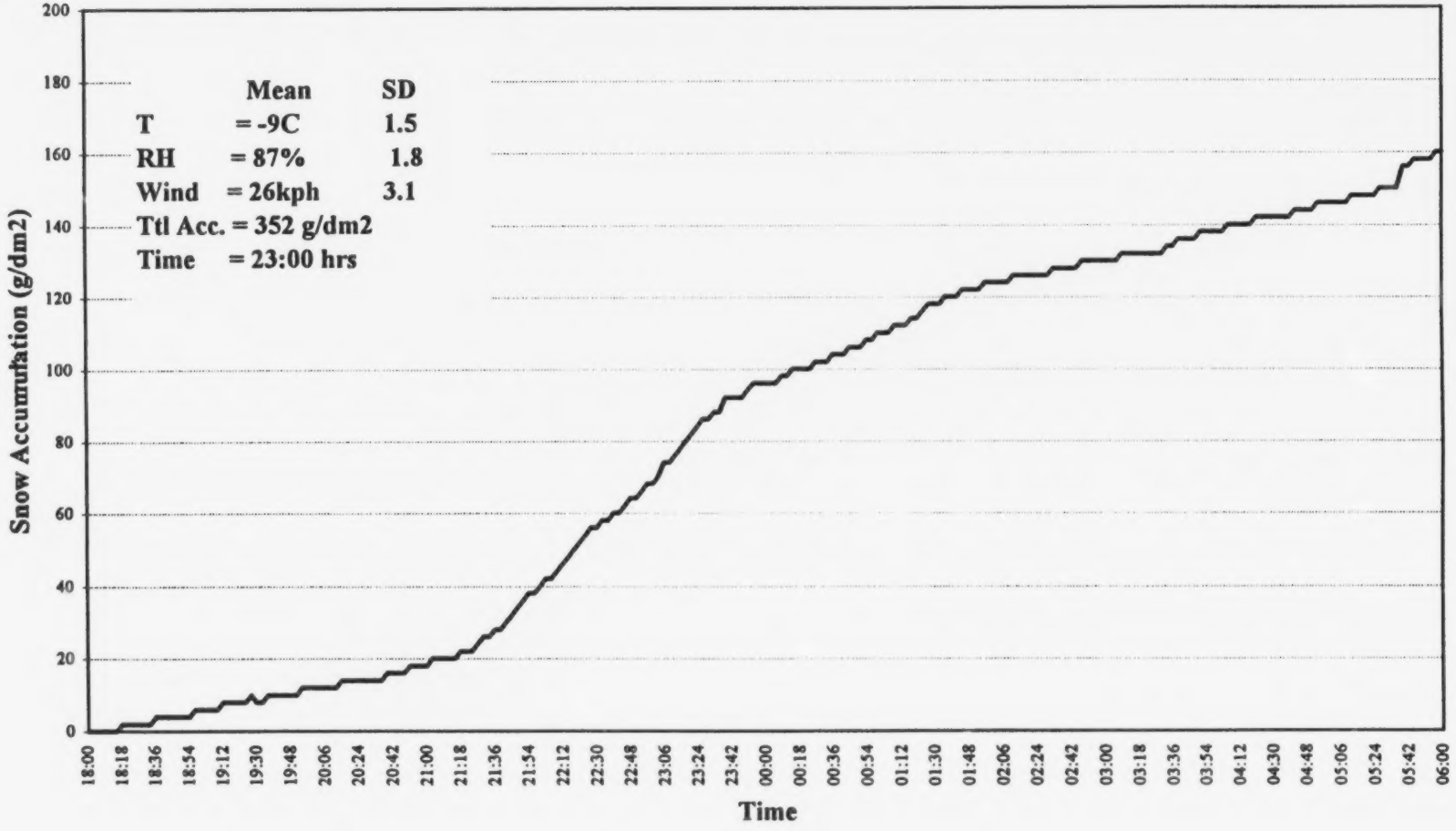
Total Snow Accumulation
for Feb. 12-13, 1993



14/8/95 15:34

FEB1294.XLS

Total Snow Accumulation
for Feb 23-24, 1994

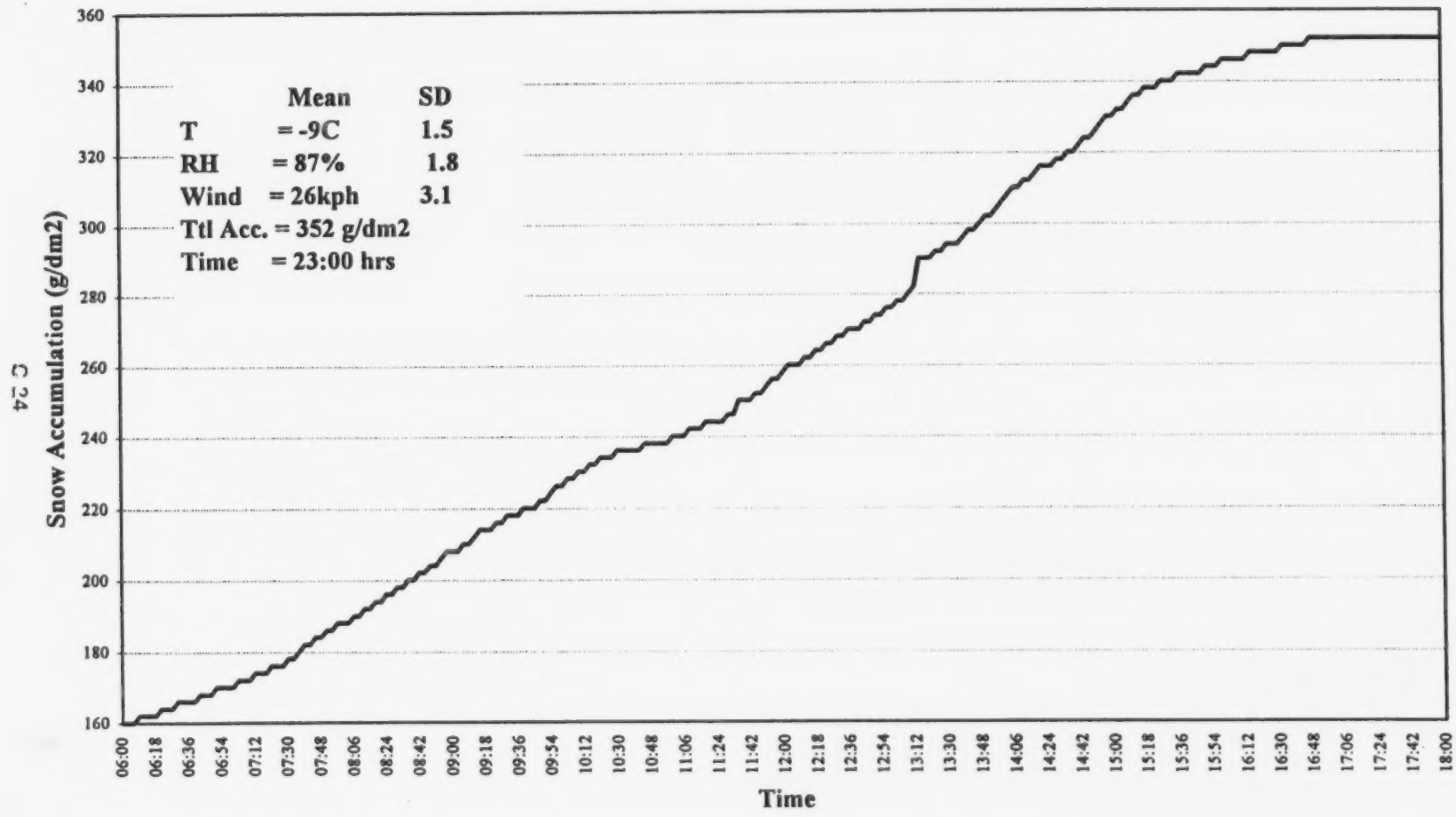


C 23

14/8/95 15:35

FEB2394.XLS

Total Snow Accumulation
for Feb 23-24, 1994

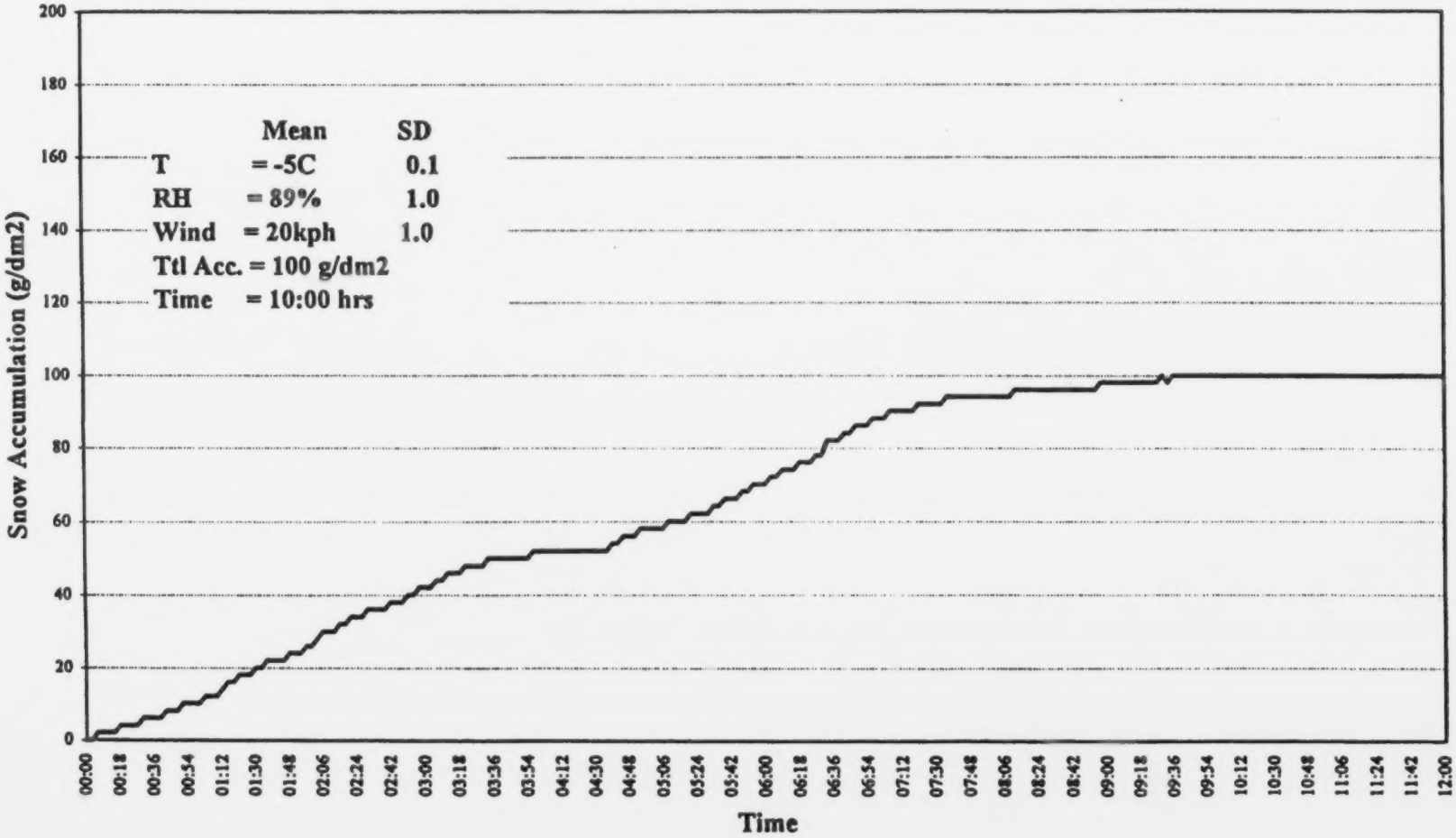


C 24

14/8/95 15:35

FEB2394.XLS

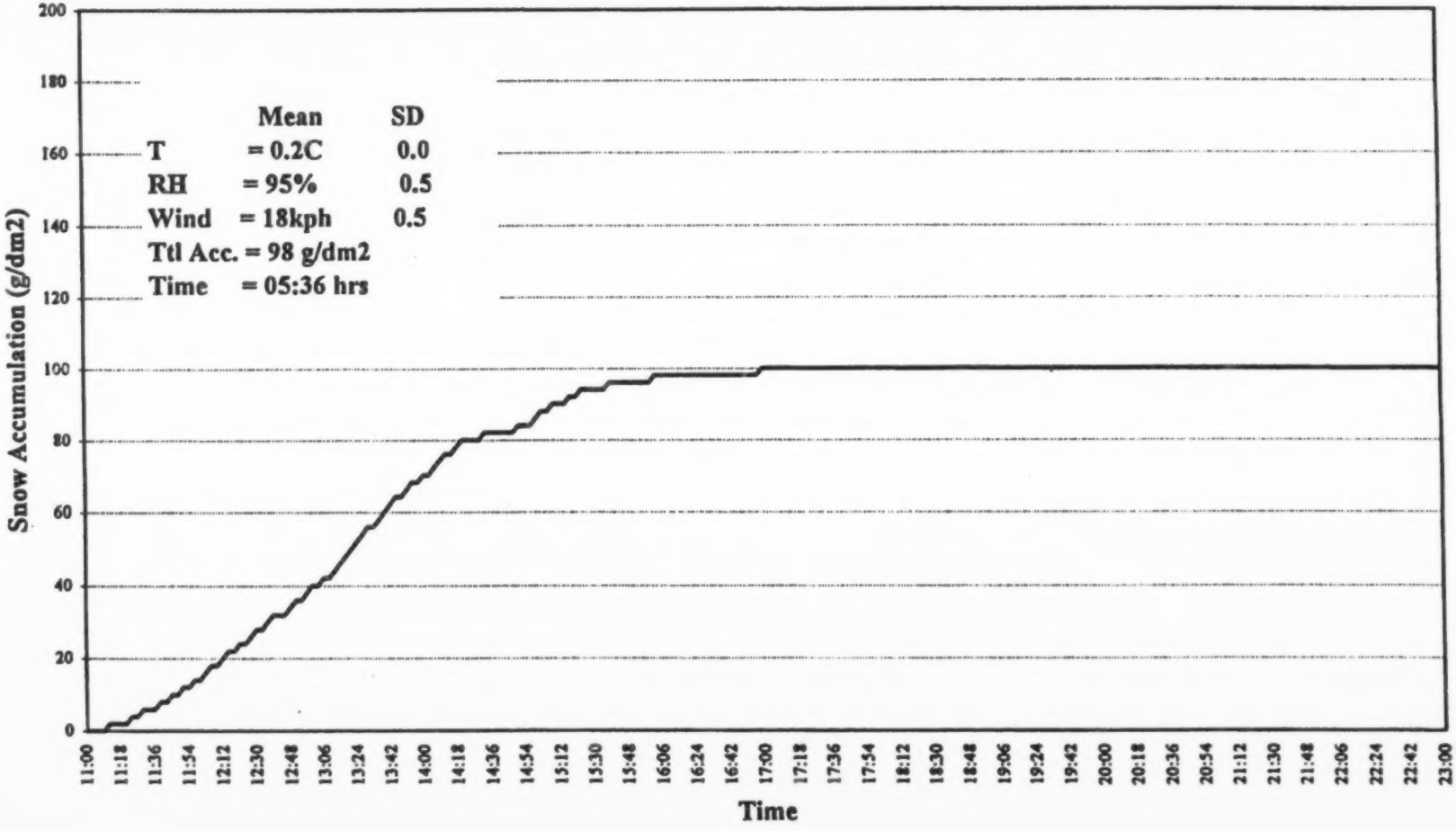
Total Snow Accumulation
for Mar. 10, 1994



14/8/95 15:37

MAR1094.XLS

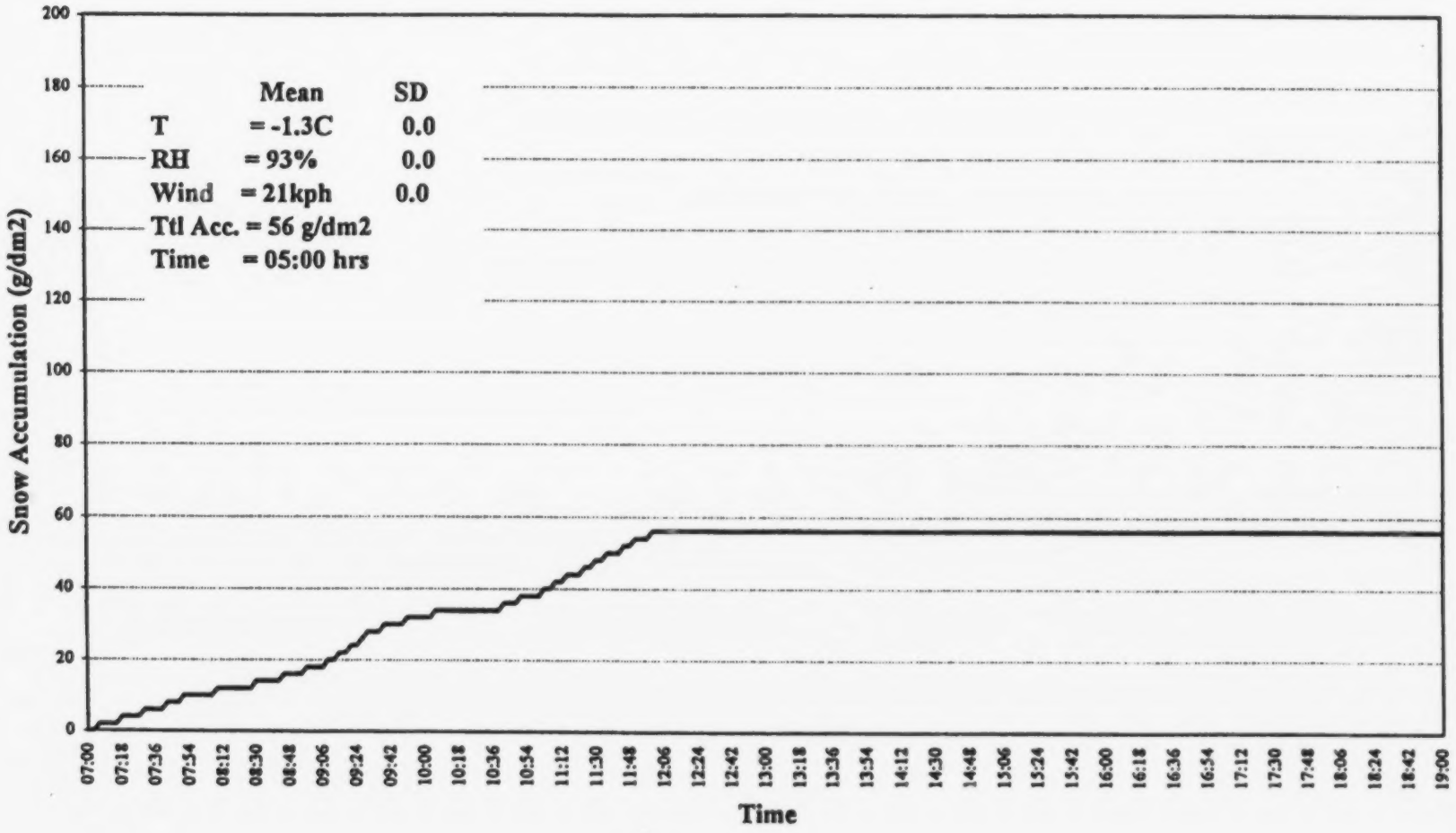
Total Snow Accumulation
for Mar. 27, 1994



14/8/95 15:36

MAR2794.XLS

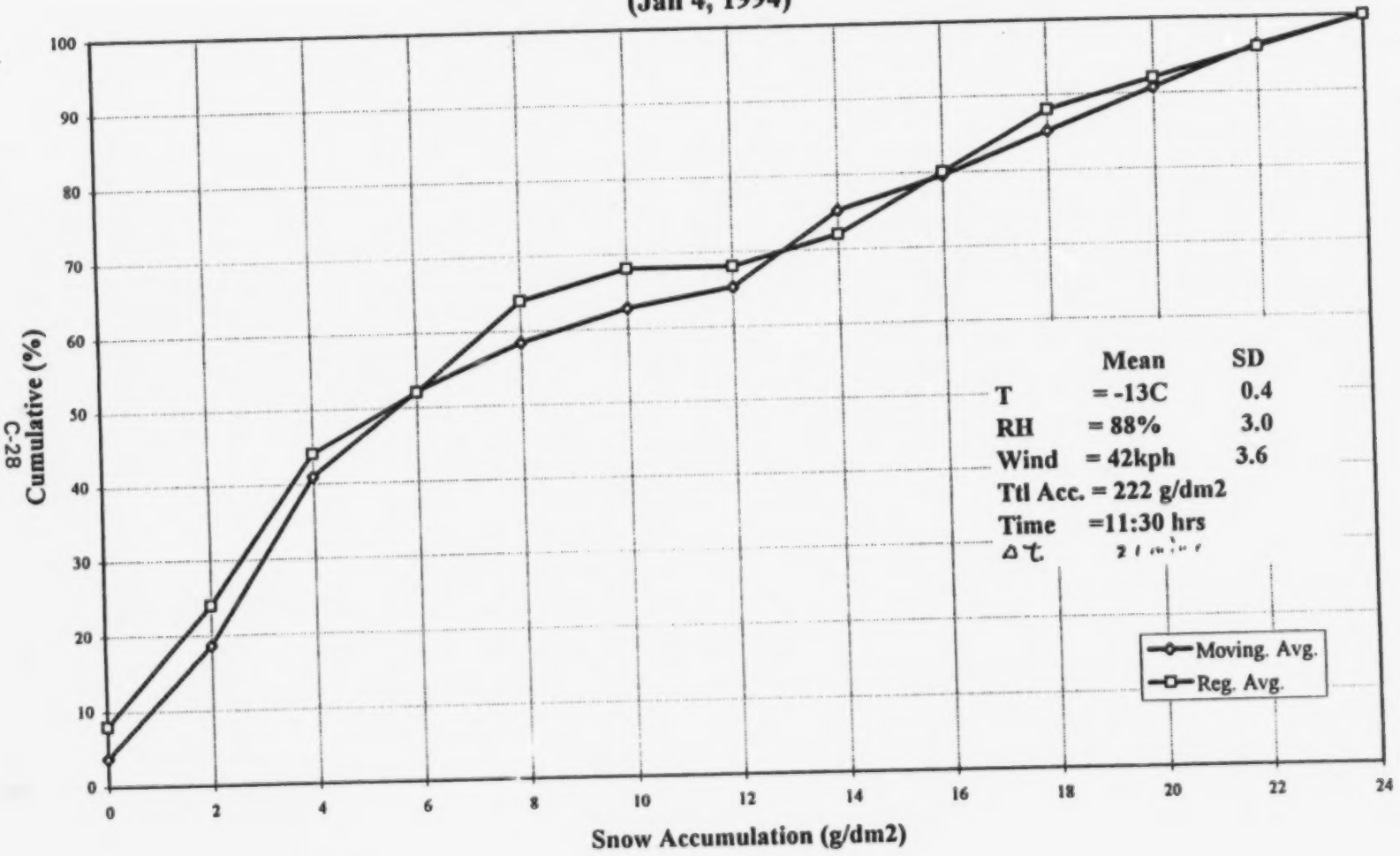
Total Snow Accumulation
for Apr. 07, 1994



14/8/95 15:38

APR0794.XLS

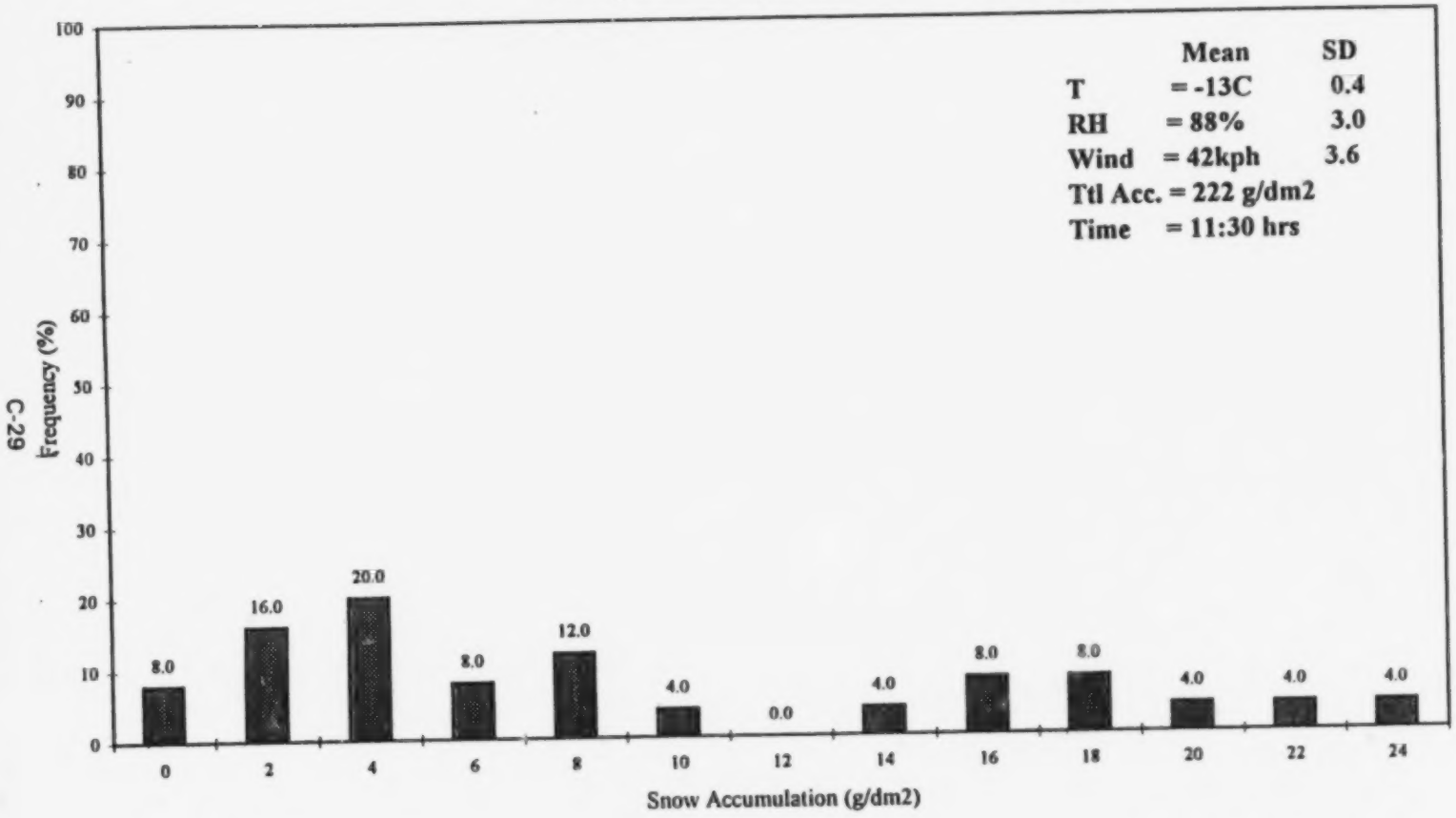
Comparison Between Moving & Reg. Averages for Distribution for Snow Accumulation (Jan 4, 1994)



JAN0494.XLS

16/8/95 14:05

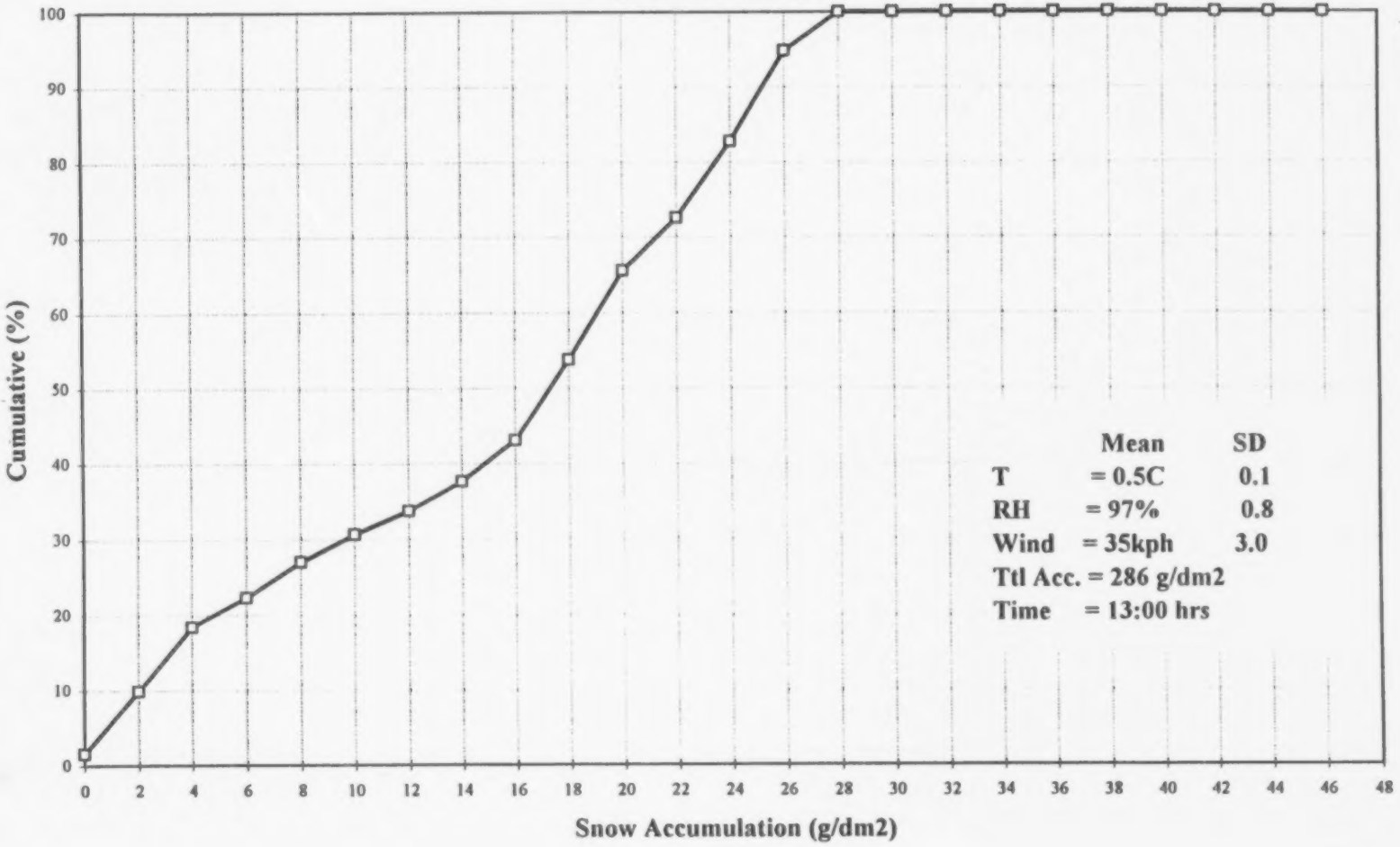
Histogram for Snow Accumulation
Every 21 min. (Series 1, Jan. 4, 1994)



18/8/95 16:47

JAN0494.XLS

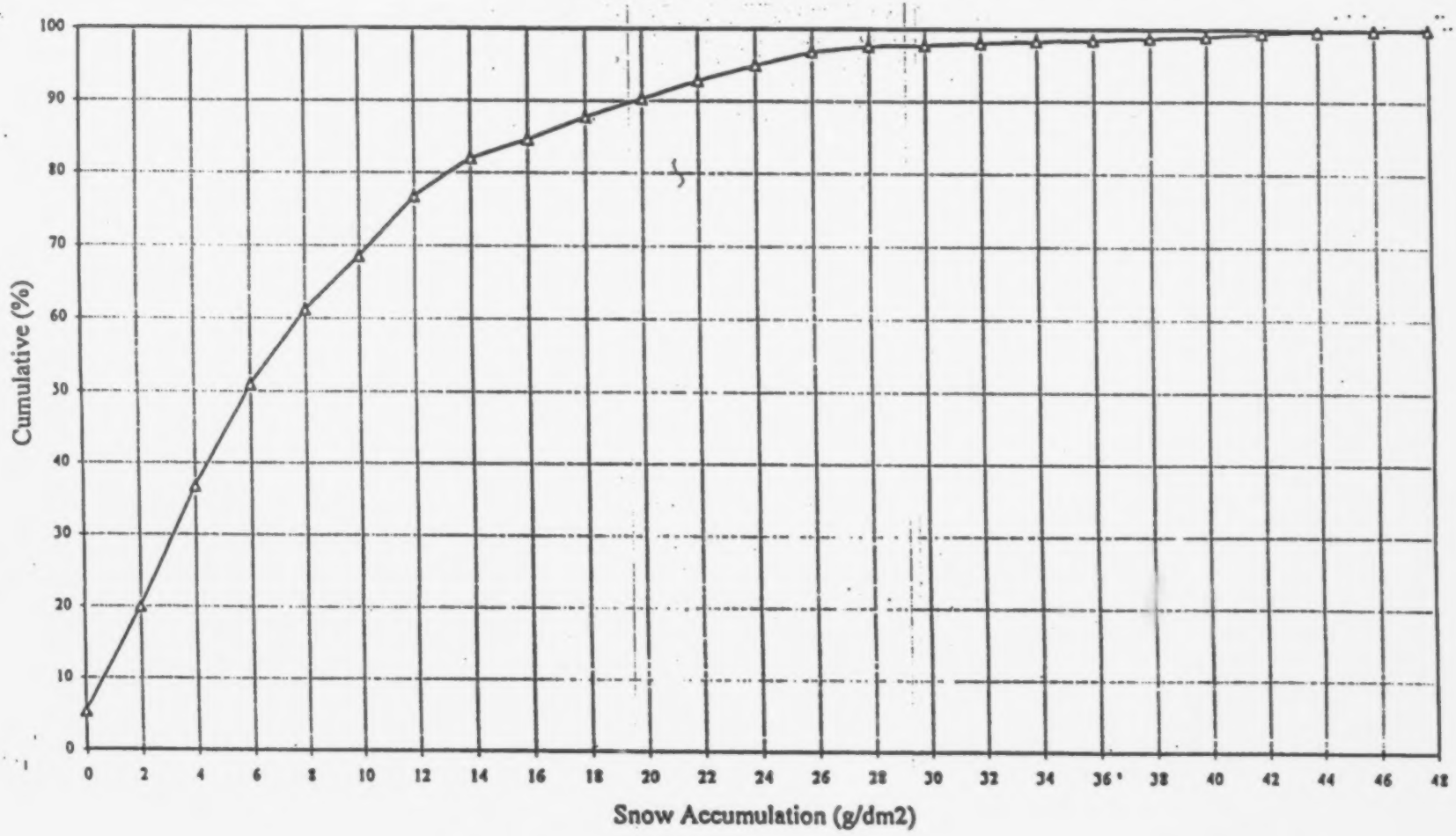
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Dec. 21, 1993)



18/8/95 16:17

DEC2193.XLS

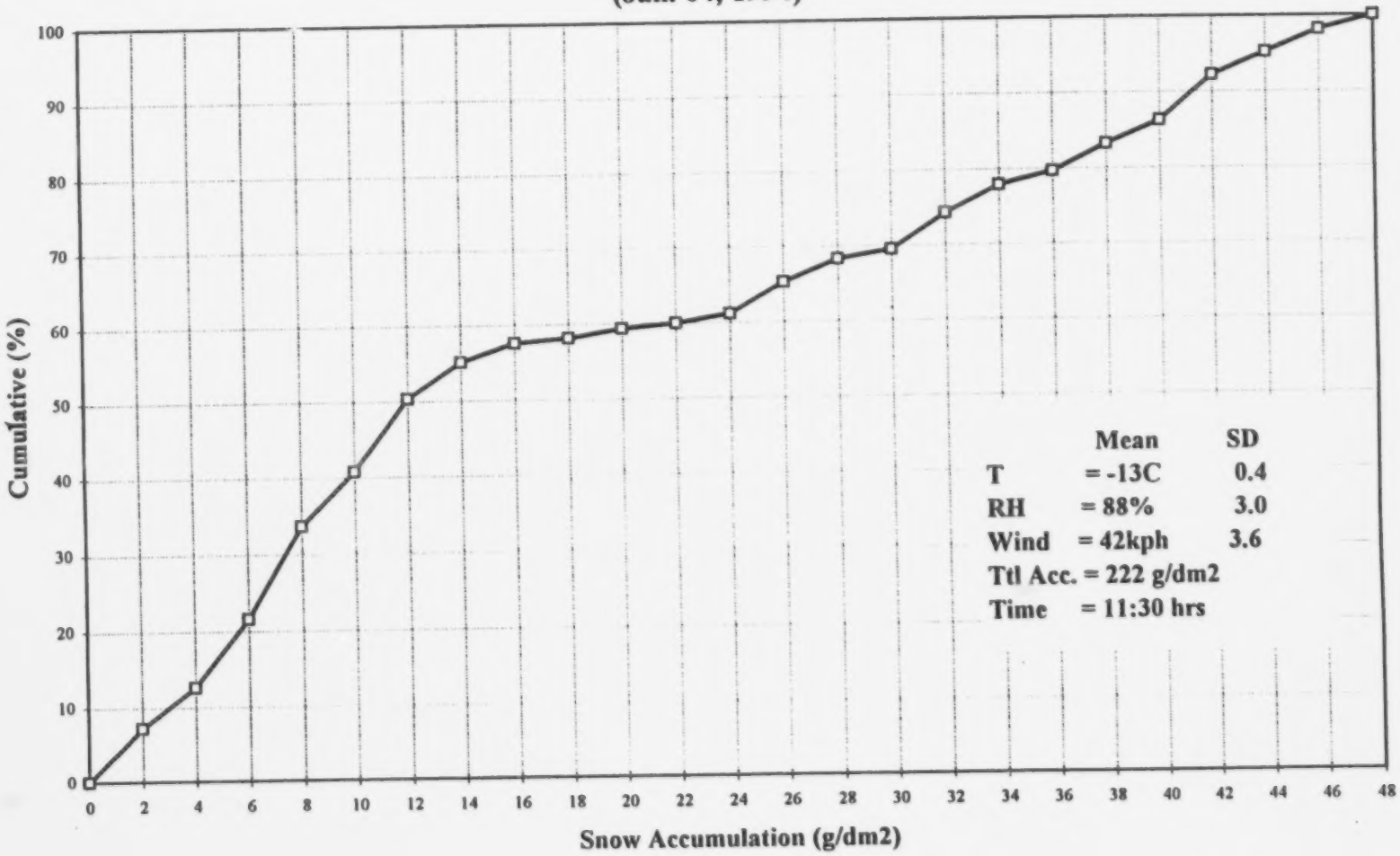
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993-1994 Winter



18/8/95 15:29

MHIST94.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 04, 1994)



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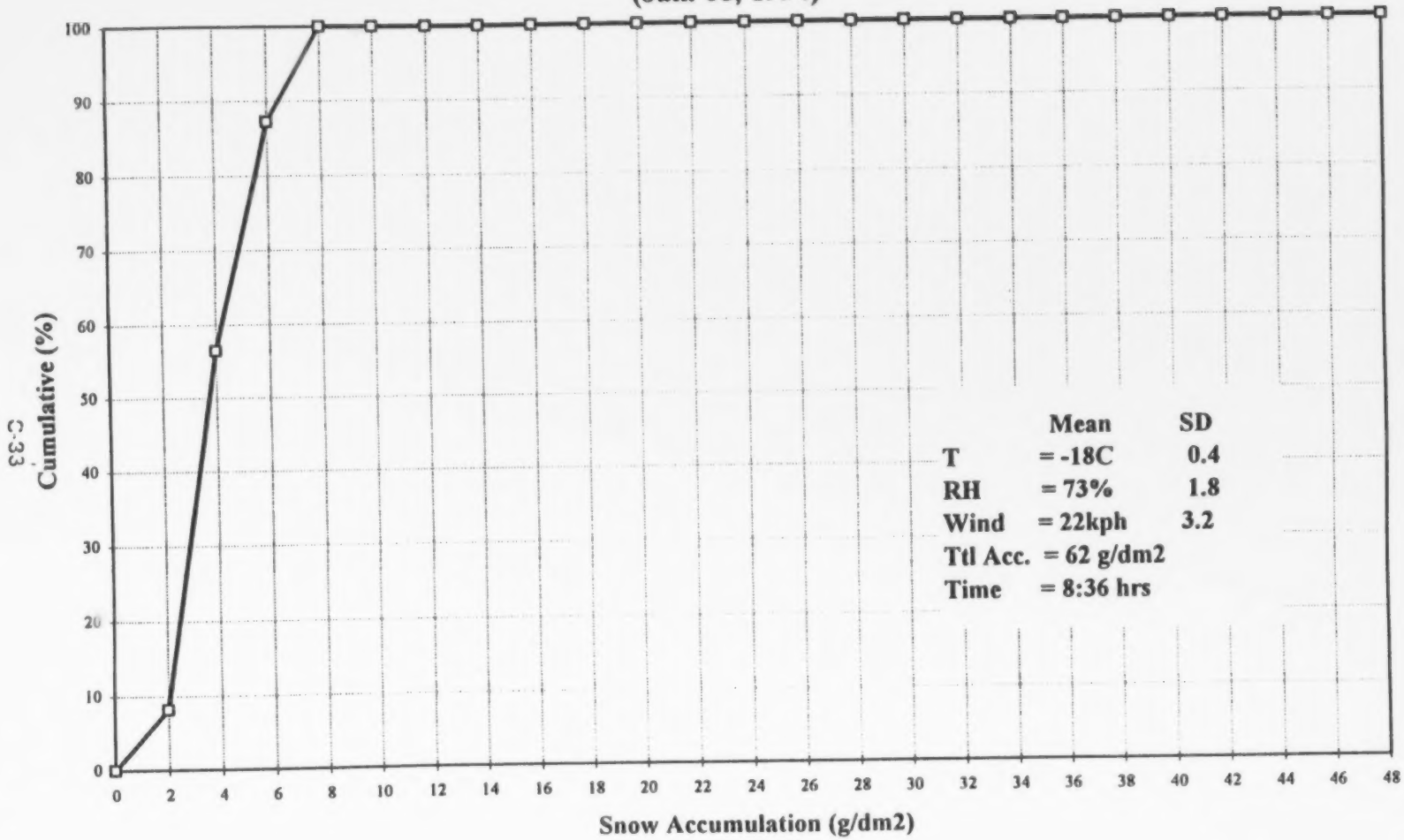
18/8/95 16:24

JAN0494.XLS

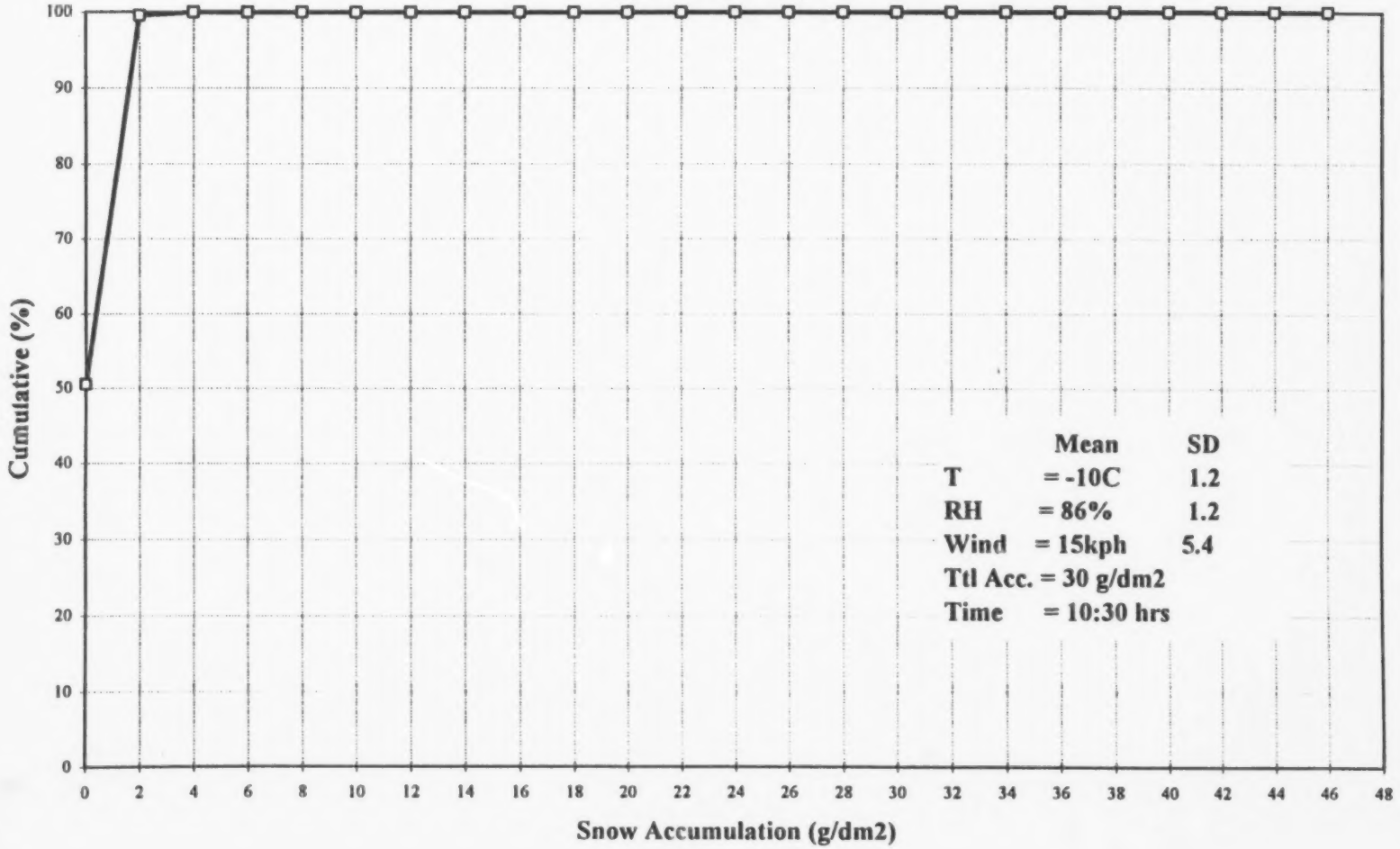
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 08, 1994)



18/8/95 16:23

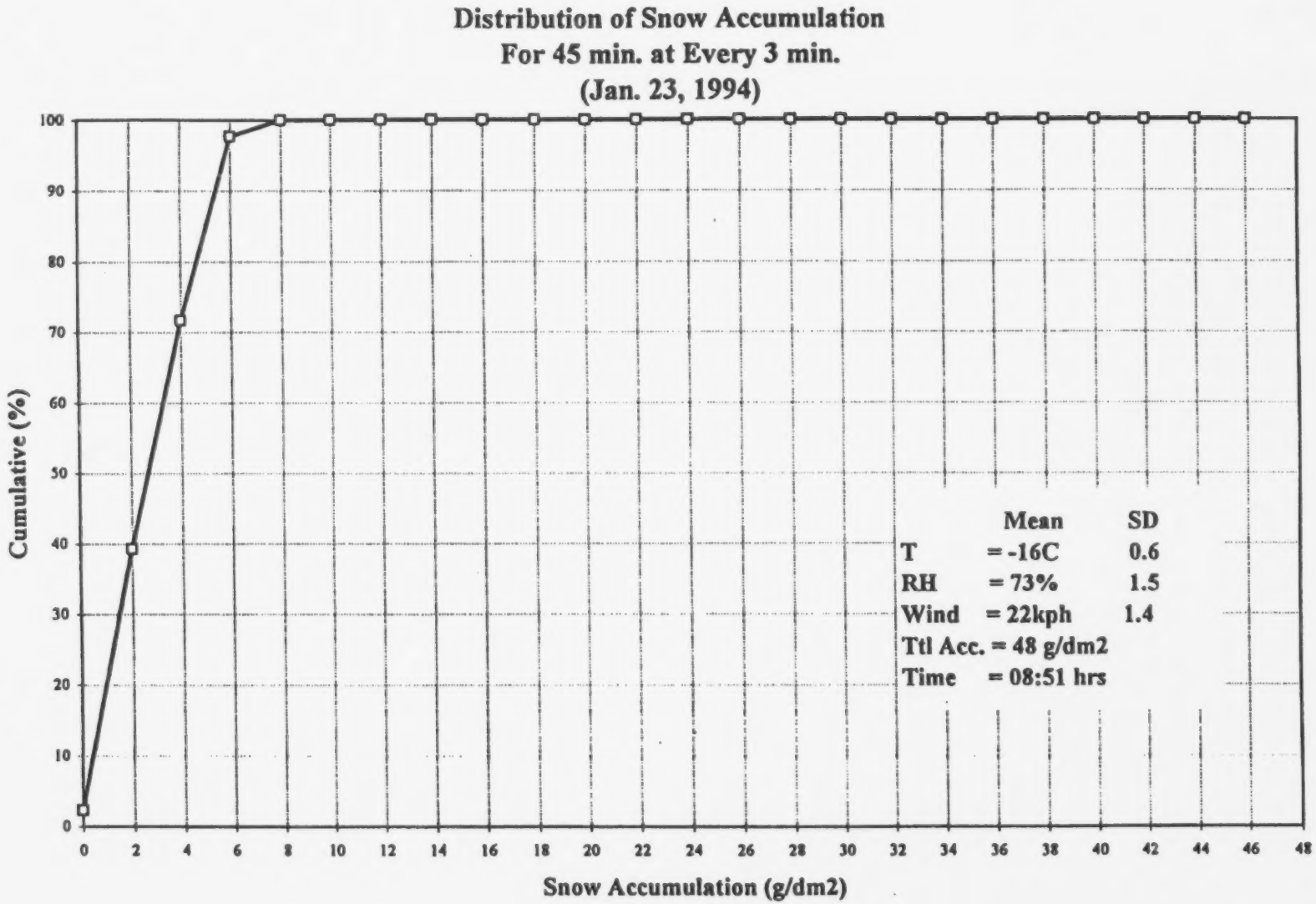
JAN0894.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 14, 1994)



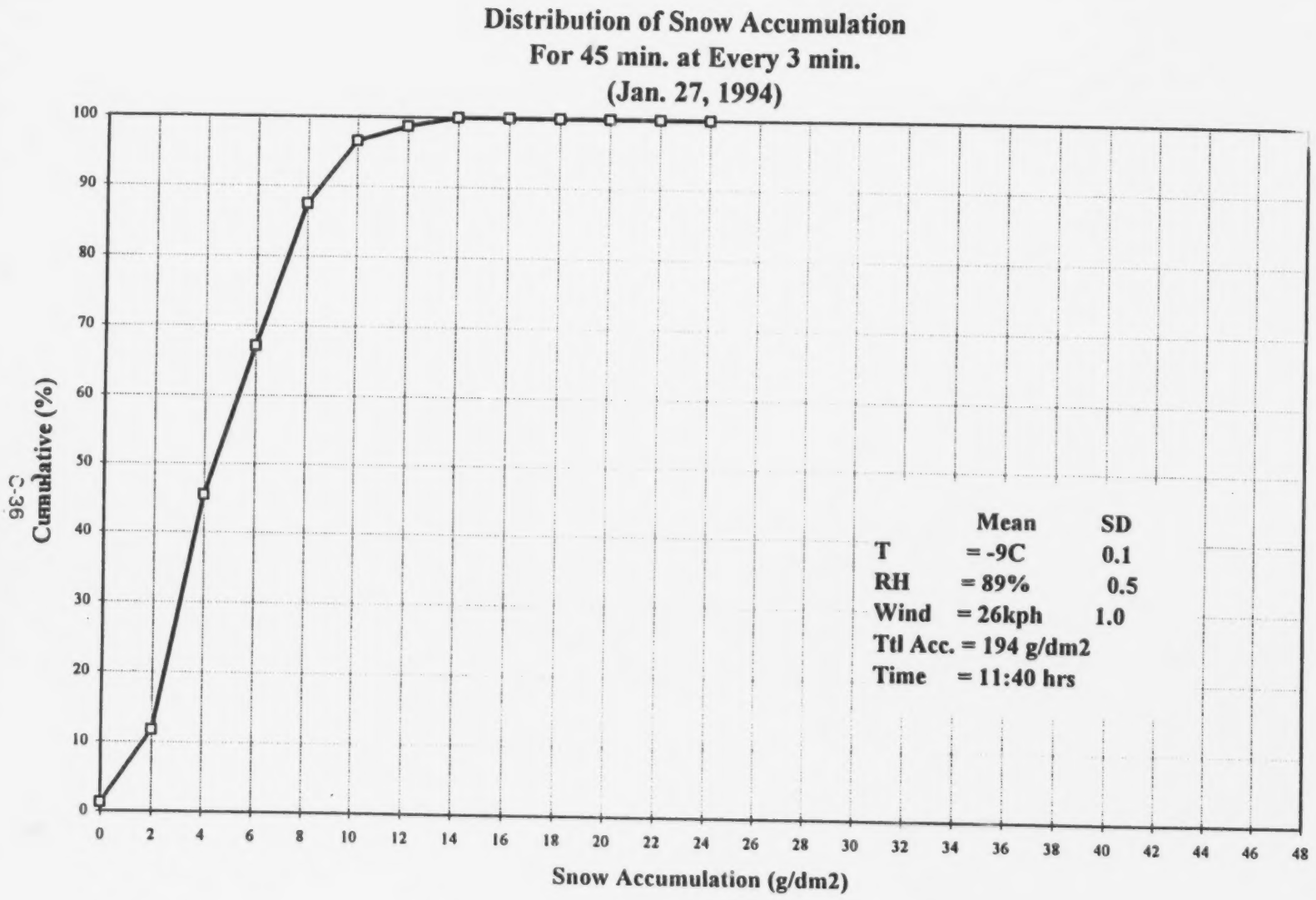
18/8/95 16:22

JAN1494.XLS



18/8/95 16:21

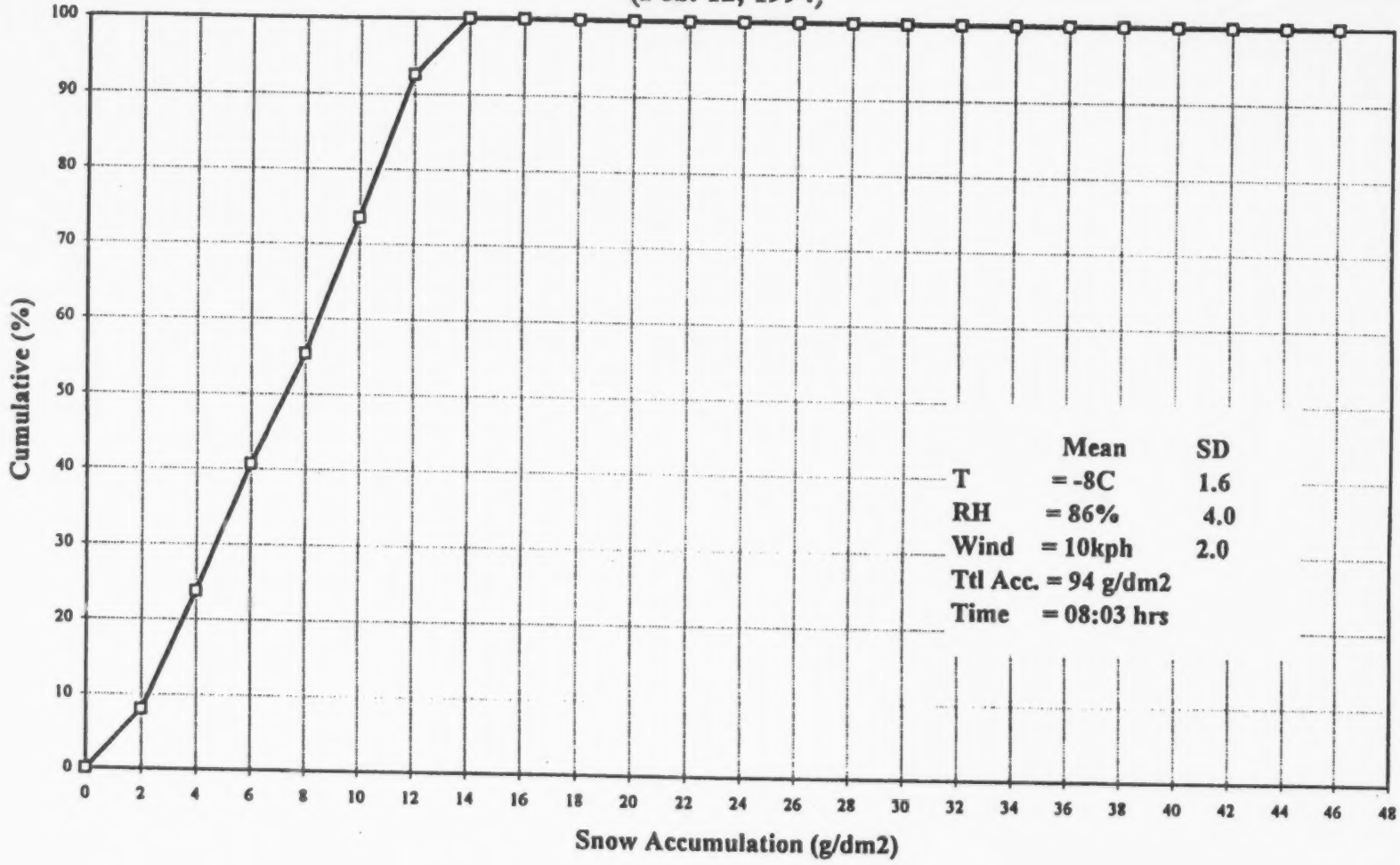
JAN2394.XLS



18/8/95 16:20

JAN2794.XLS

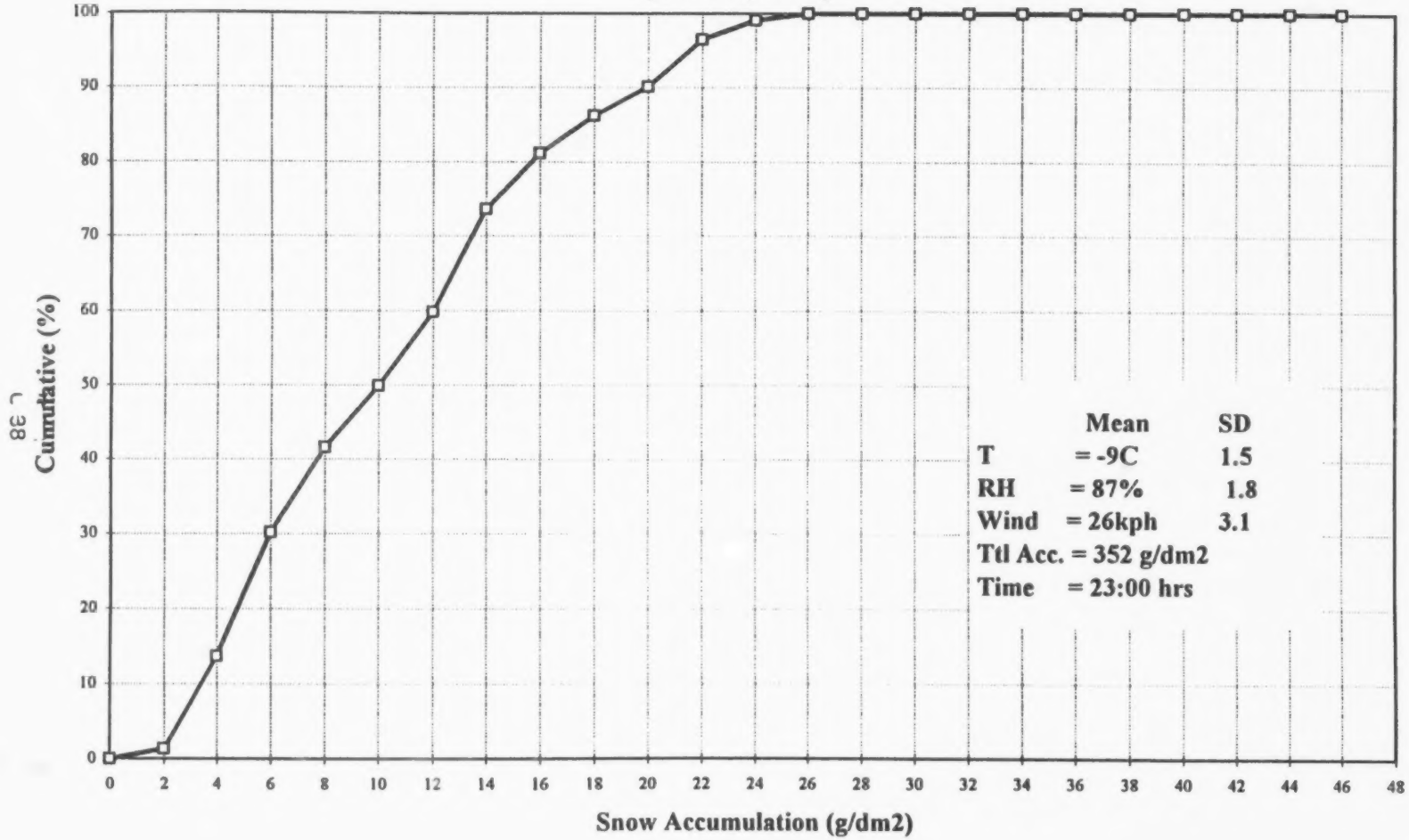
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 12, 1994)



18/8/95 16:28

FEB1294.XLS

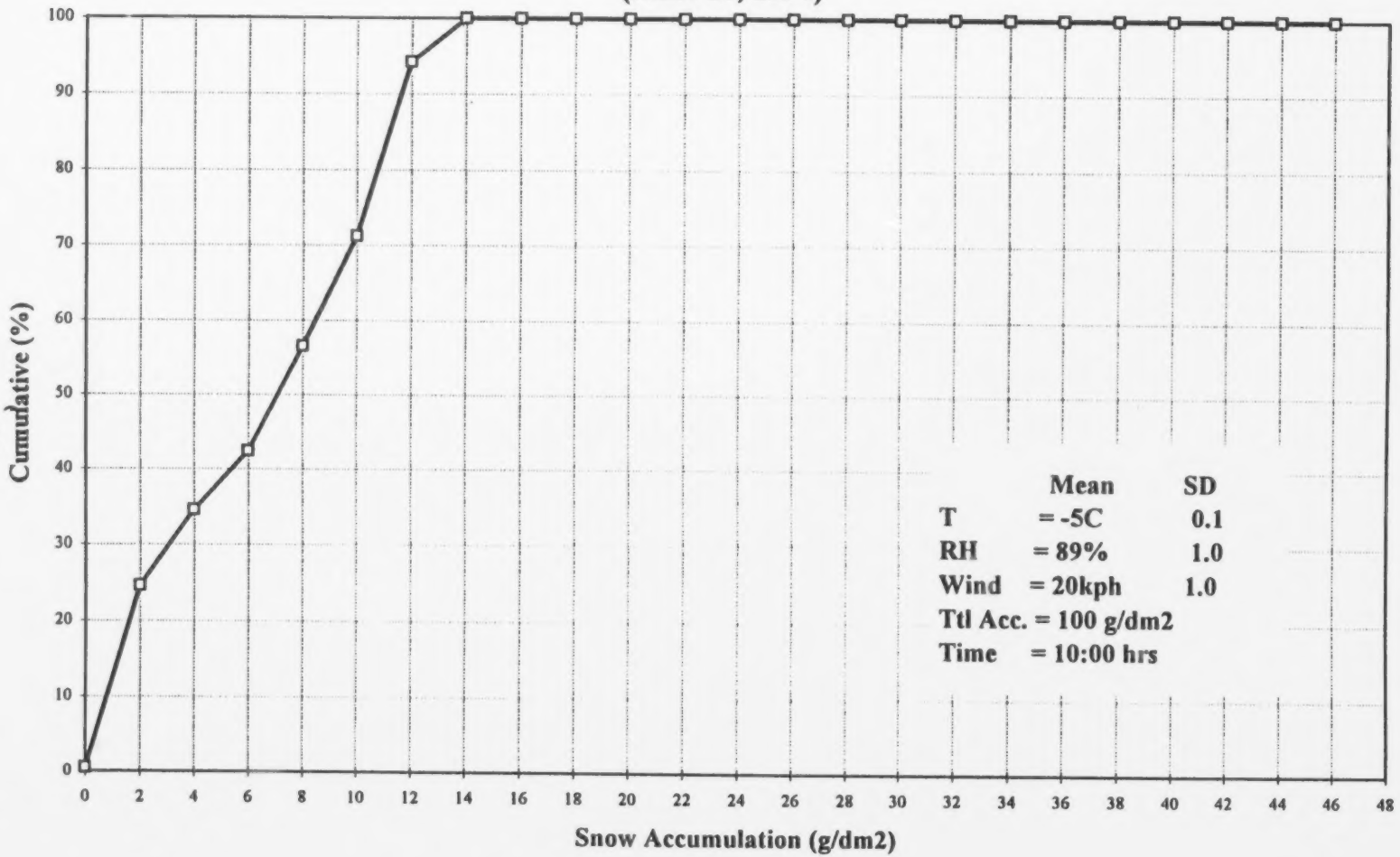
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 23, 1994)



18/8/95 16:27

FEB2394.XLS

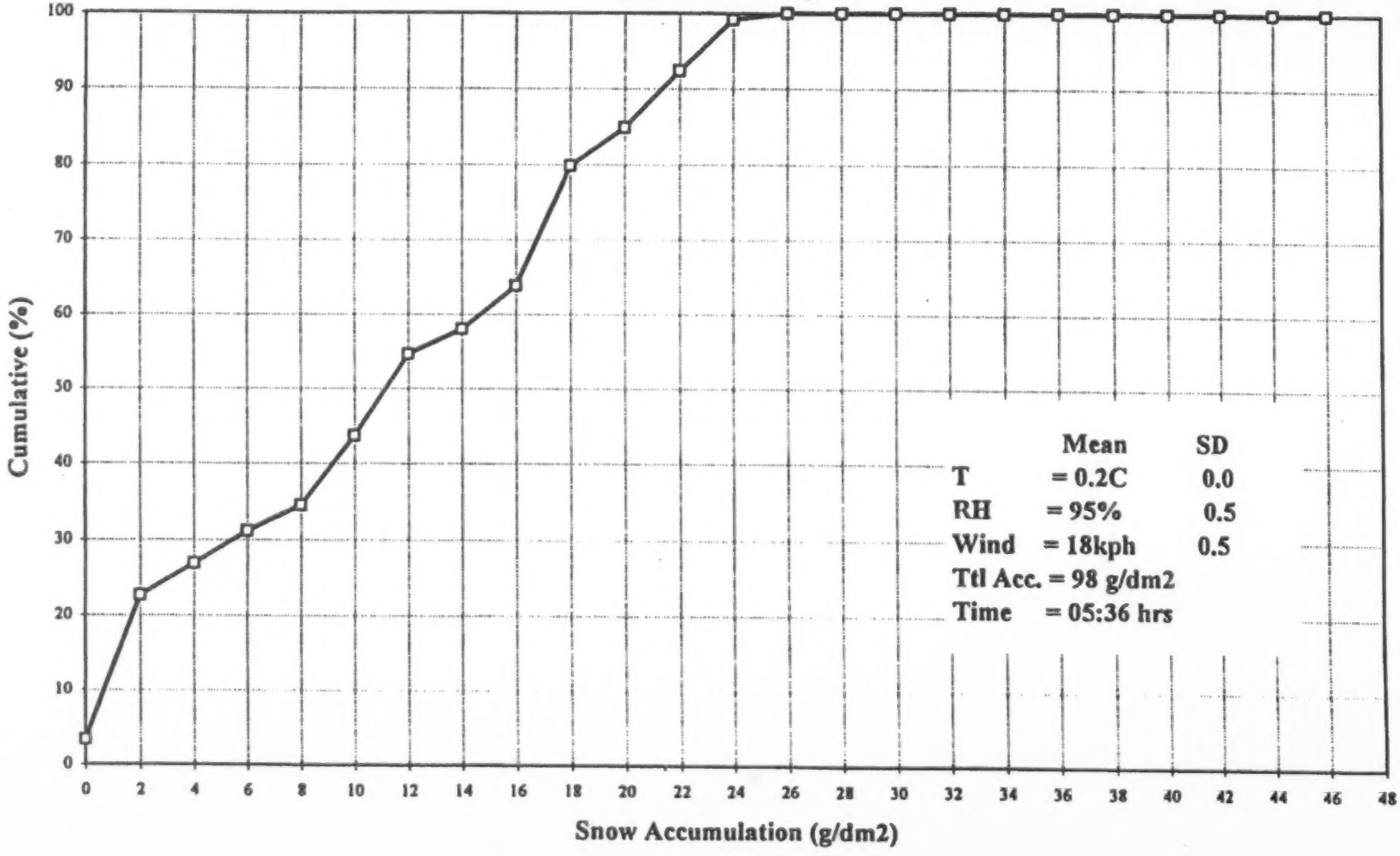
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 10, 1994)



18/8/95 16:31

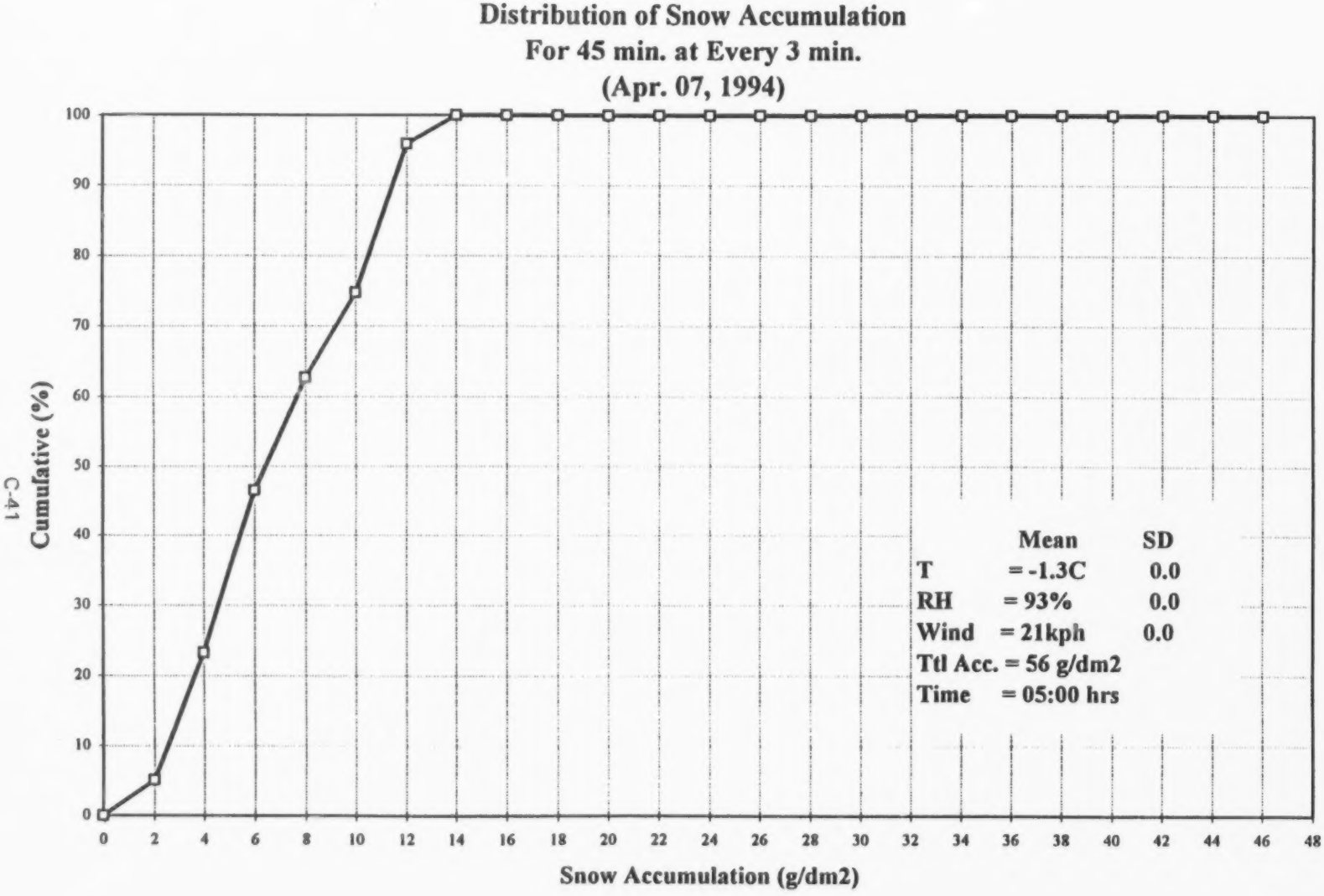
MAR1094.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 27, 1994)



18/8/95 16:30

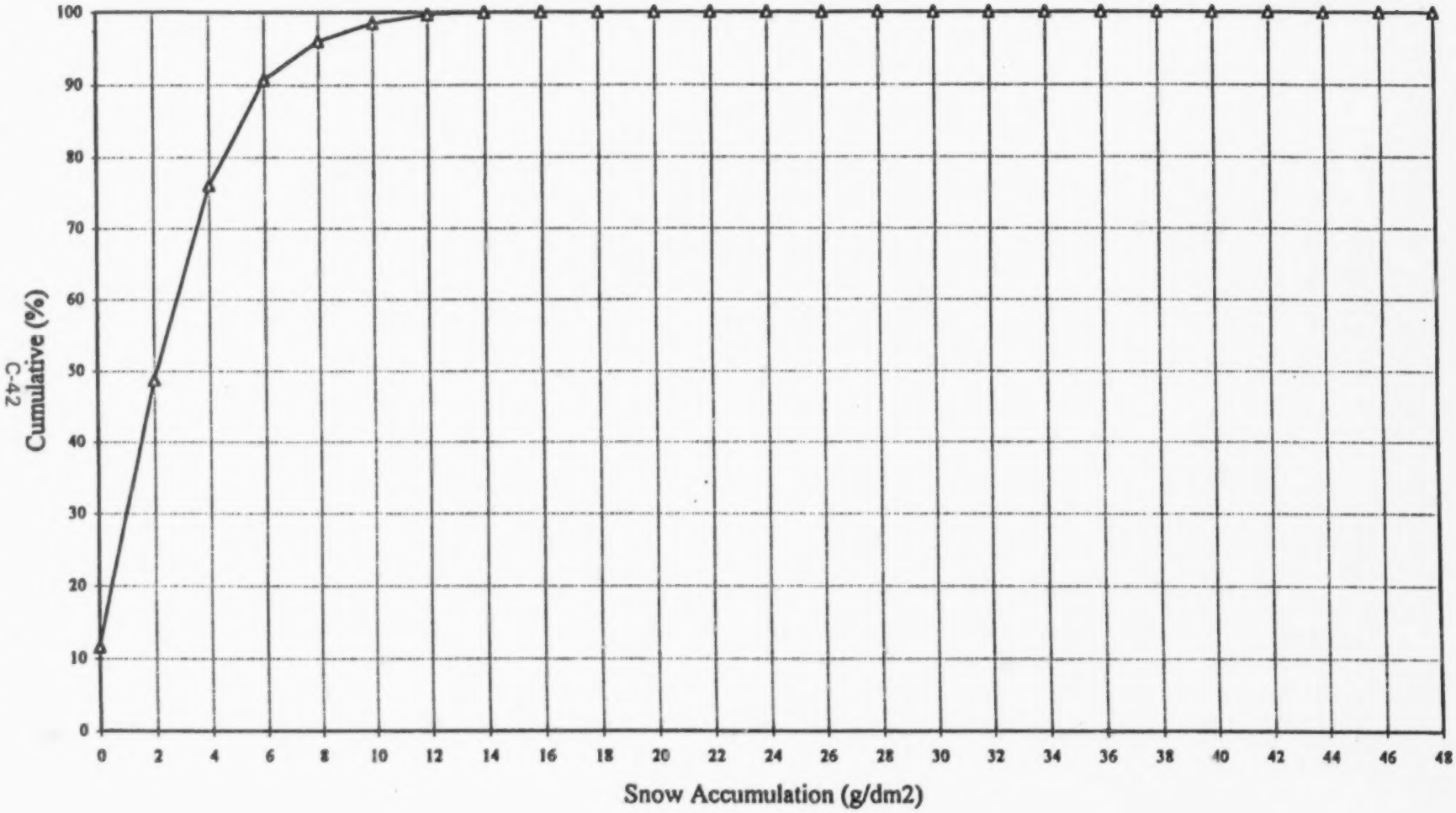
MAR2794.XLS



18/8/95 16:33

APR0794.XLS

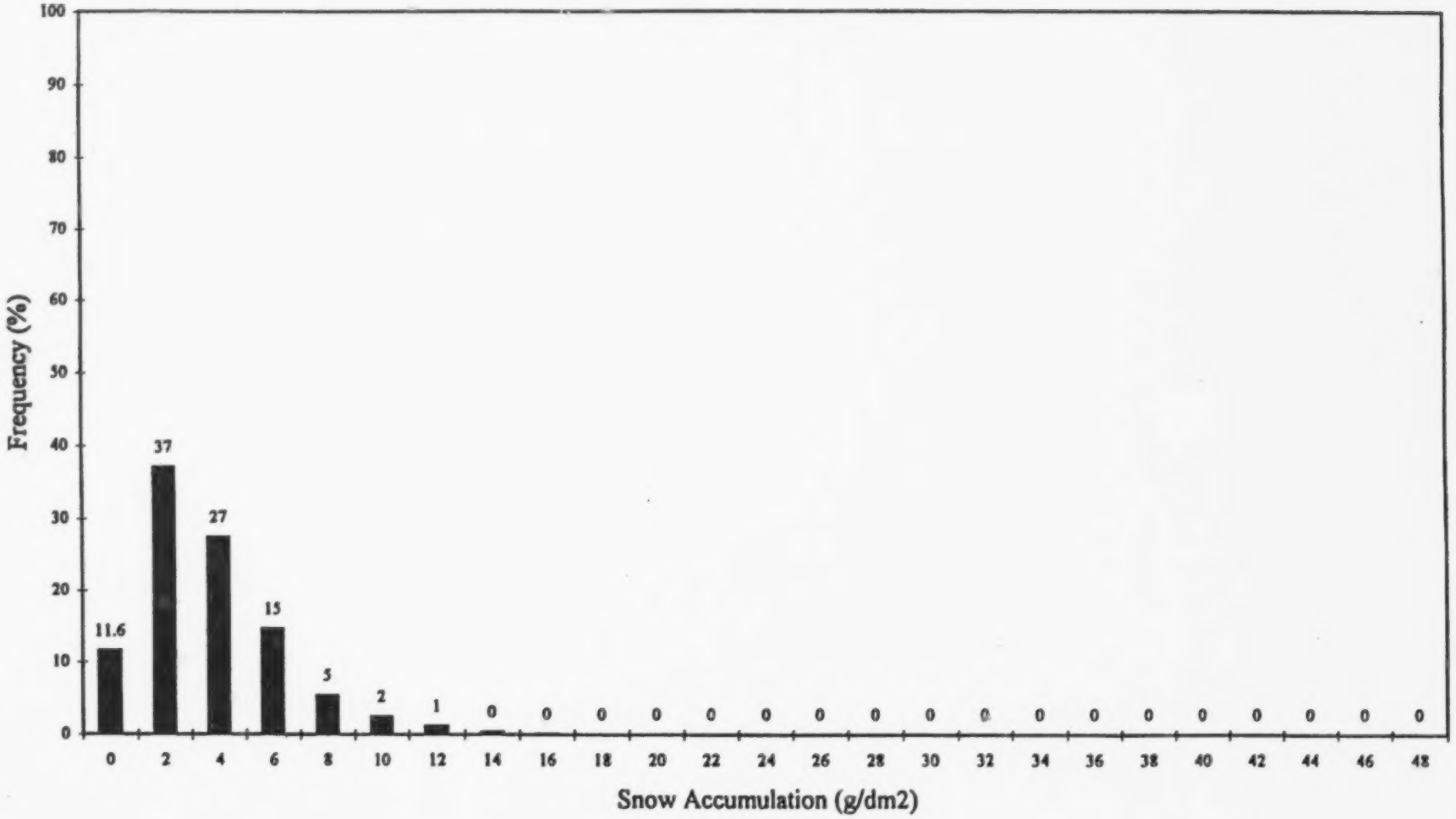
Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1994-1995 Winter



18/8/95 15:25

MHIST95.XLS

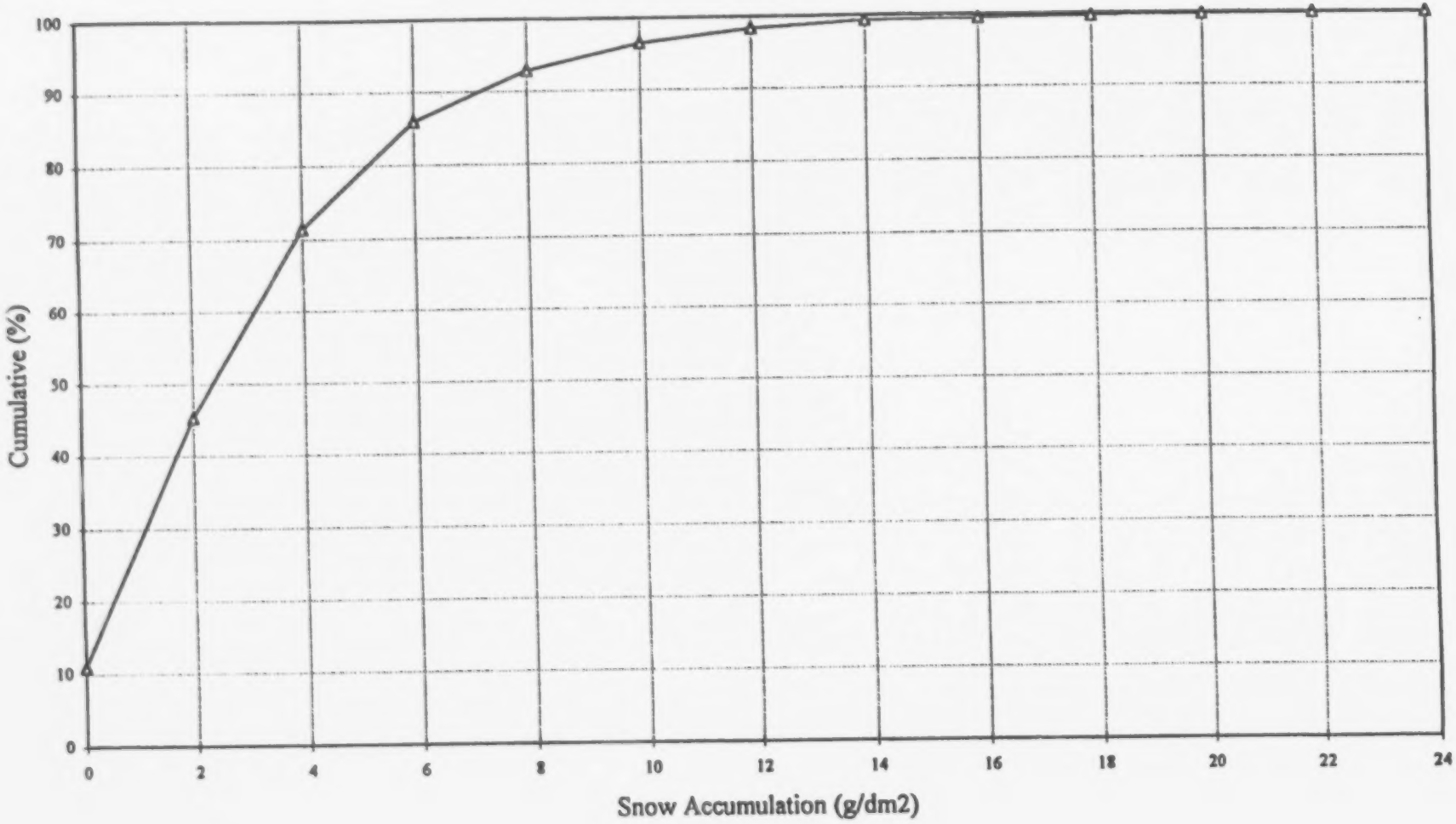
Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994-1995 Winter



18/8/95 11:36

MHIST95.XLS

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



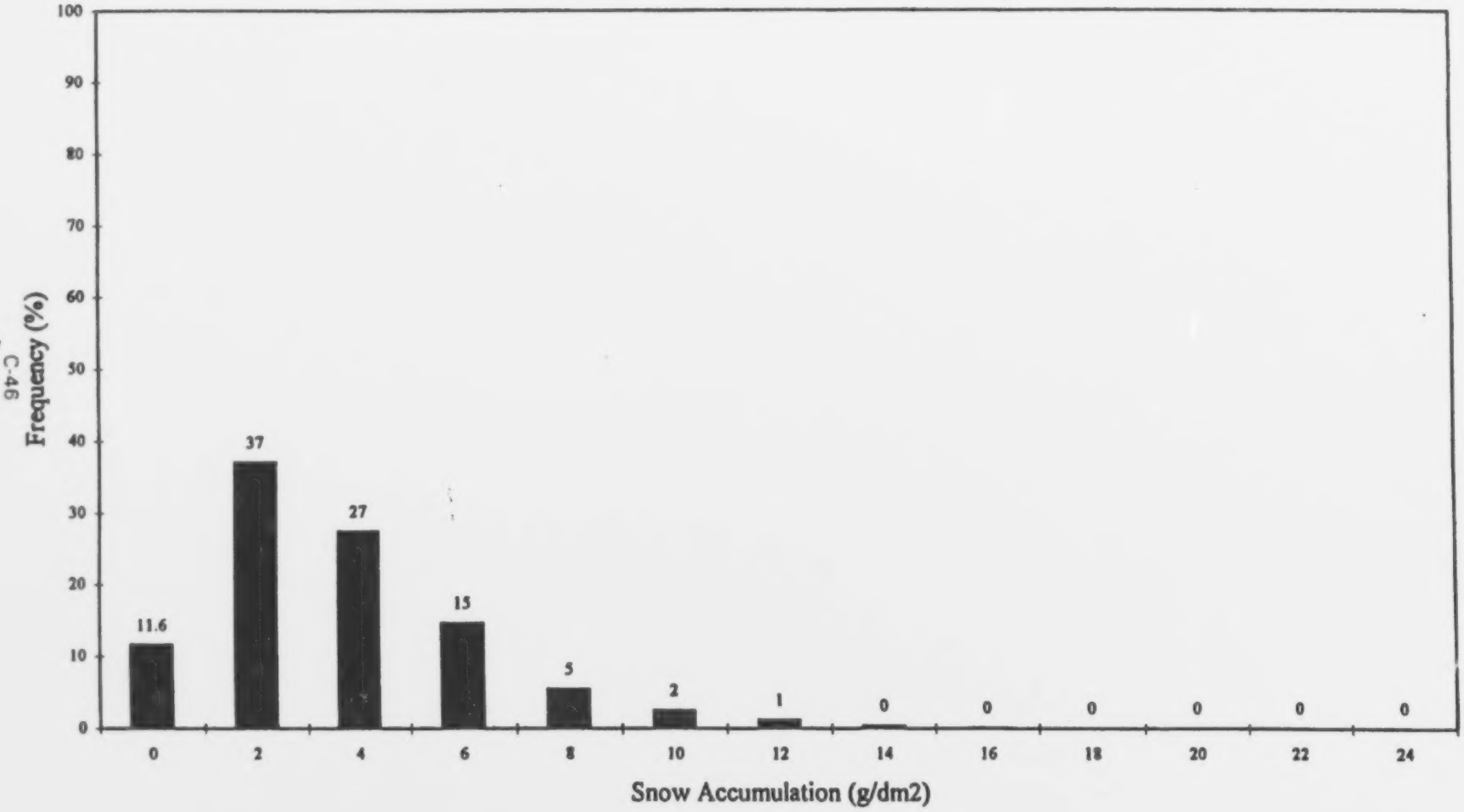
18/8/95 15:25

MHIST95.XLS

MOVING AVERAGE
1994/1995

RANGE	950107	950112	950204	950211	950216	950224	950227	950306	950308A	950308B	950308C	SUM	%	CUMUL.
0	100	16	116	123	0	85	44	23	0	0	3	510	11.6	11.6
1	76	86	117	118	7	41	101	93	3	40	58	740	16.8	28.4
2	108	115	34	129	14	151	121	14	12	26	164	888	20.2	48.6
3	74	91	26	53	53	36	152	13	22	31	83	634	14.4	63.1
4	78	77	13	47	67	29	121	17	6	6	109	570	13.0	76.0
5	56	45	0	17	43	6	48	32	1	17	129	394	9.0	85.0
6	61	11	0	16	46	9	4	26	8	18	51	250	5.7	90.7
7	6	25	0	9	34	0	1	36	3	17	28	159	3.6	94.3
8	5	13	0	2	24	0	0	13	6	11	1	75	1.7	96.0
9	0	6	0	0	11	0	0	20	13	15	0	65	1.5	97.5
10	0	0	0	0	18	0	0	10	5	10	0	43	1.0	98.5
11	0	0	0	0	7	0	0	7	15	4	0	33	0.8	99.2
12	0	1	0	0	6	0	0	2	8	1	0	18	0.4	99.6
13	0	0	0	0	1	0	0	0	4	4	0	9	0.2	99.8
14	0	0	0	0	0	0	0	0	5	1	0	6	0.1	100.0
15	0	0	0	0	0	0	0	0	2	0	0	2	0.0	100.0
16	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
17	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
18	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
19	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
20	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
21	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
22	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
23	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
24	0	0	0	0	0	0	0	0	0	0	0	0	0.0	100.0
												4396		

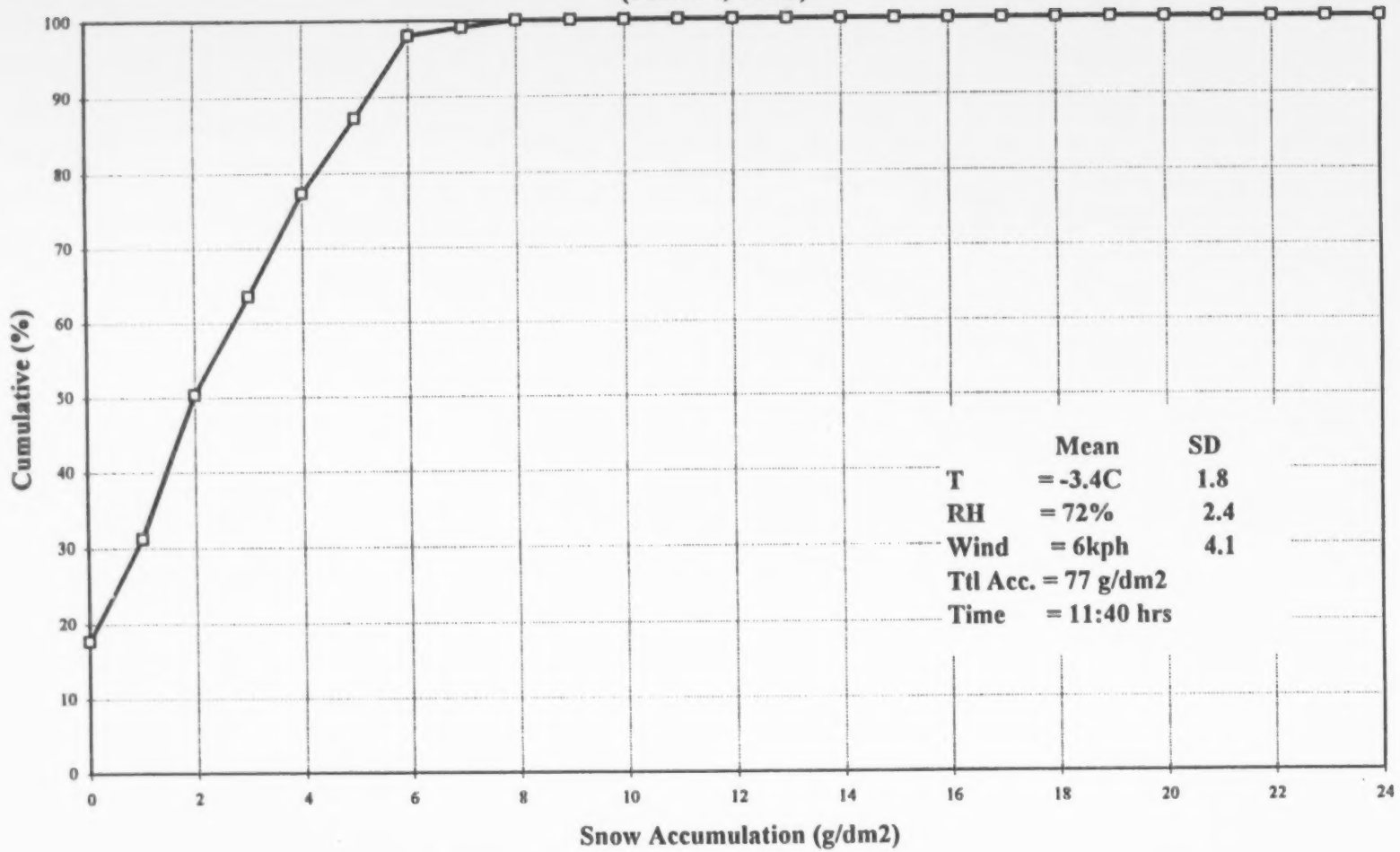
Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1994-1995 Winter



17/8/95 11:48

MHIST95.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Jan. 07, 1995)



17/8/95 13:23

950107.XLS

Distribution of Snow Accumulation
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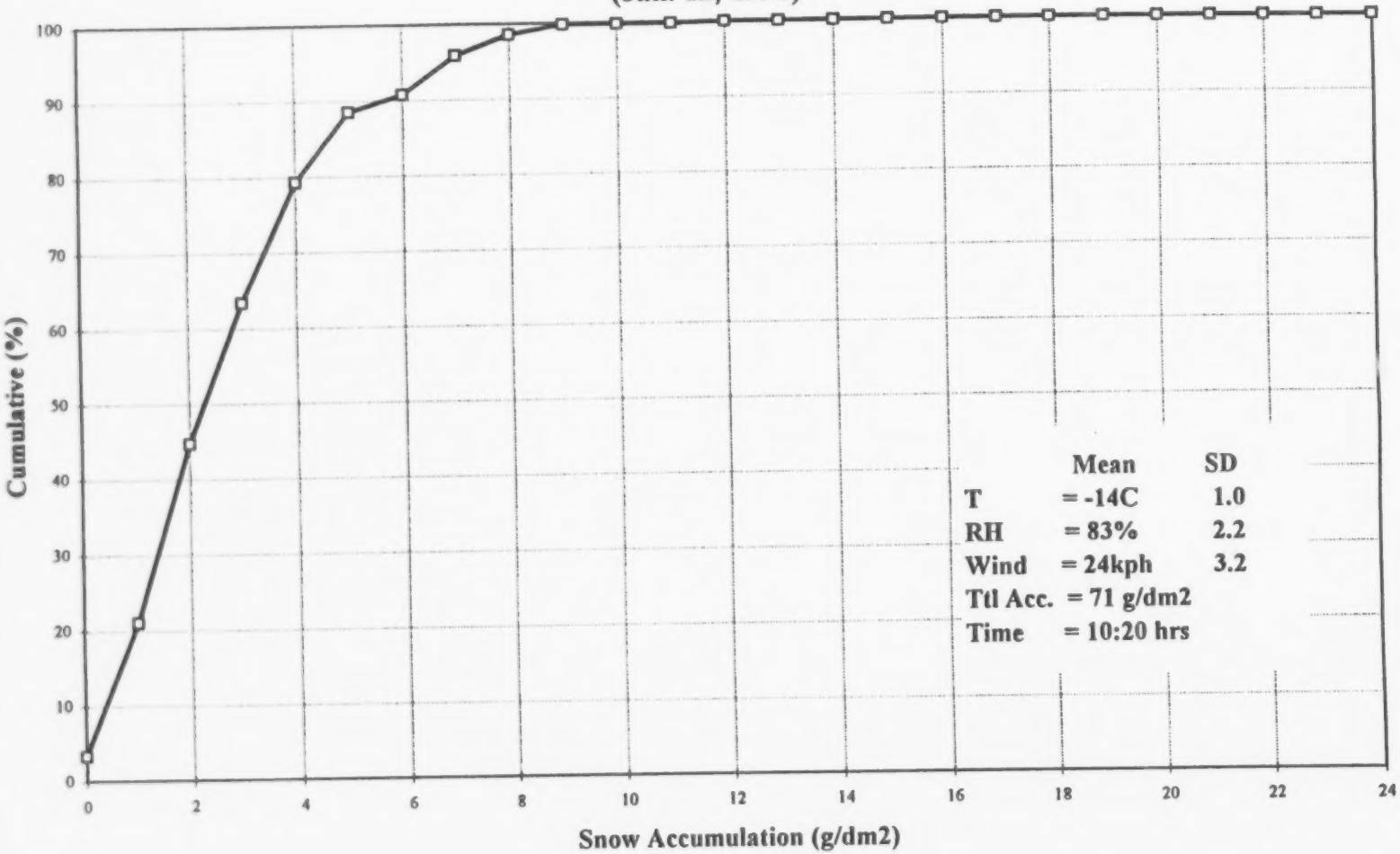
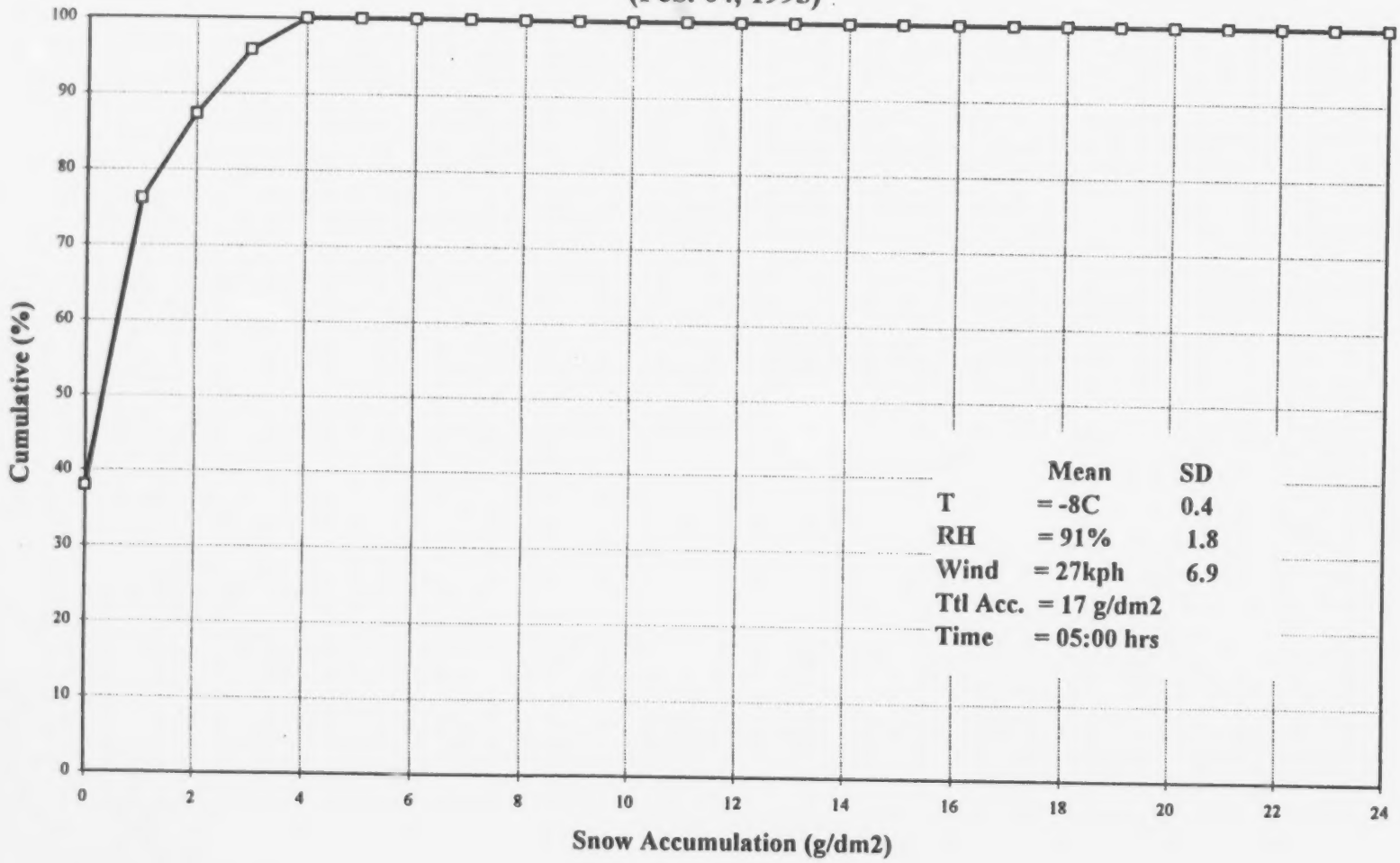
(Jan. 12, 1995)



18/8/95 15:34

950112.XLS

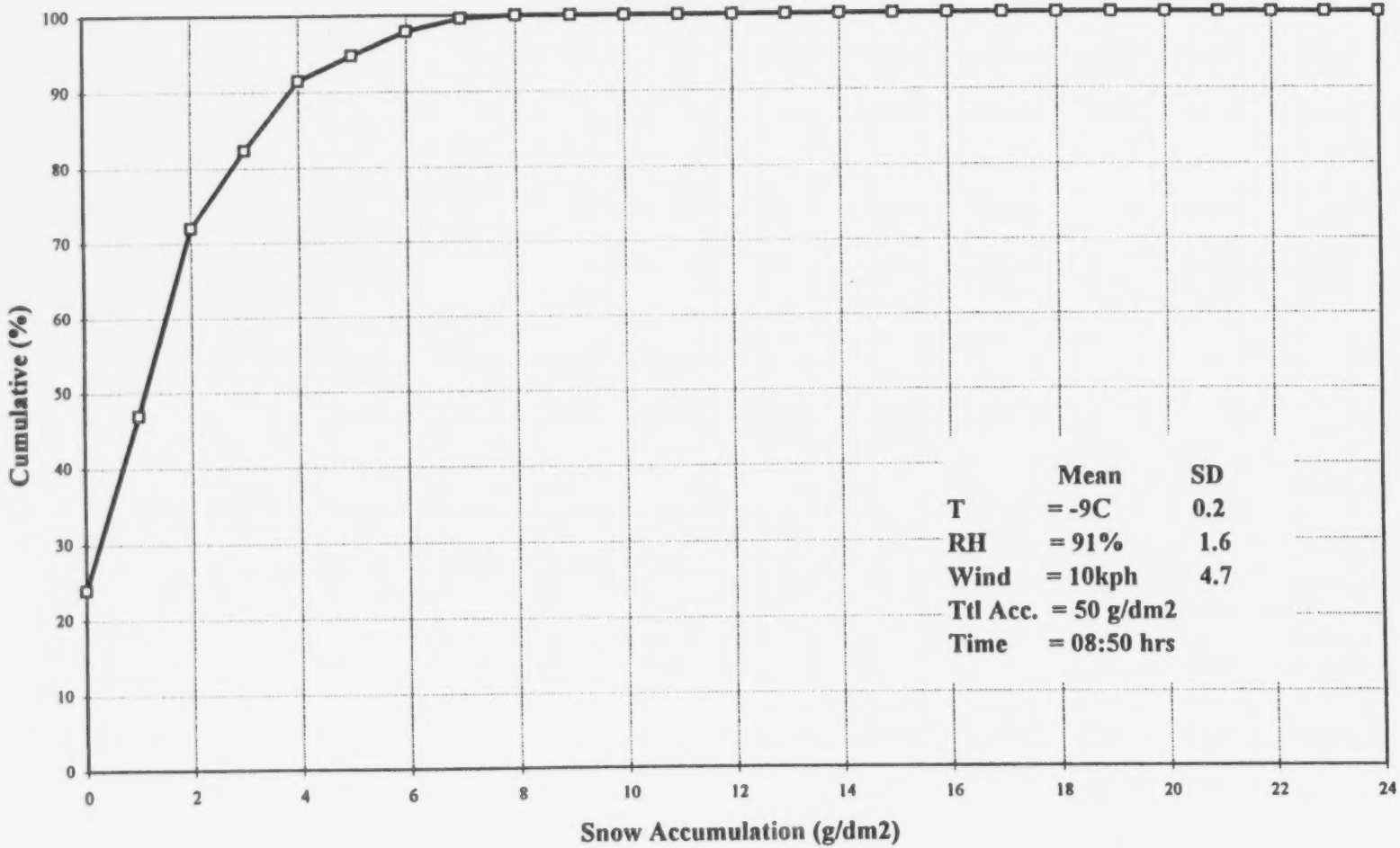
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 04, 1995)



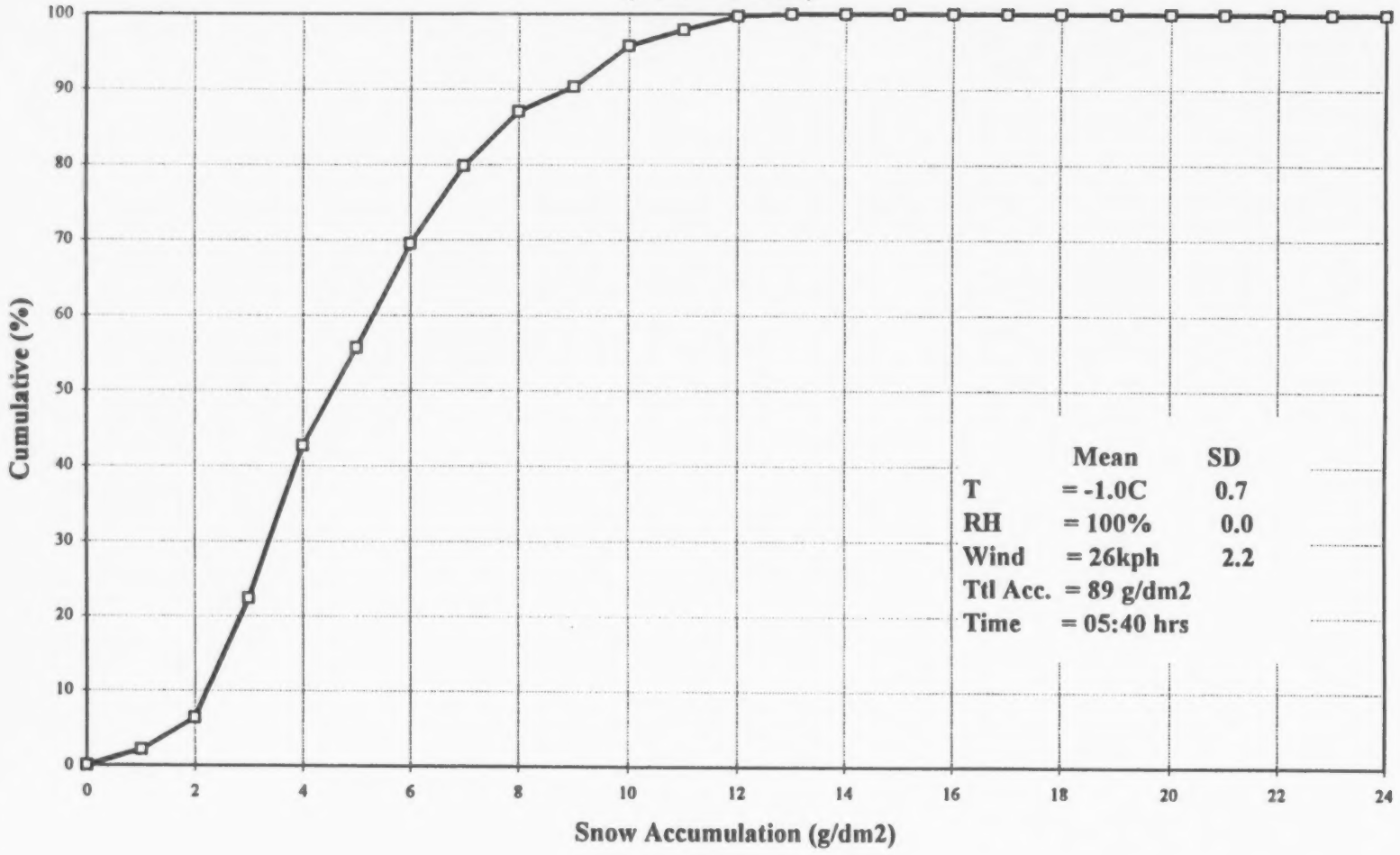
17/8/95 13:29

950204.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 11, 1995)



Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 16, 1995)



17/8/95 13:32

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Distribution of Snow Accumulation
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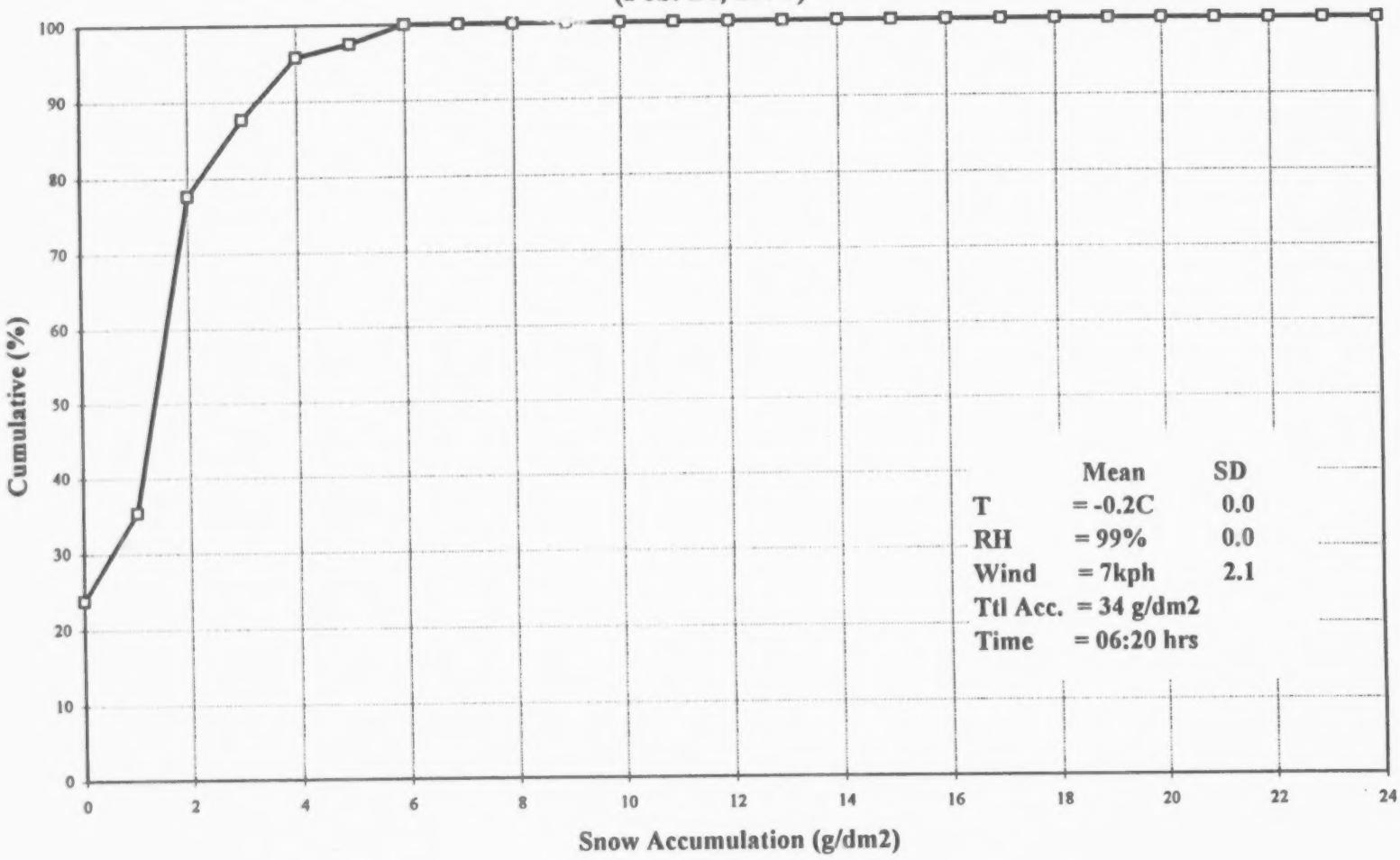
(Feb. 24, 1995)



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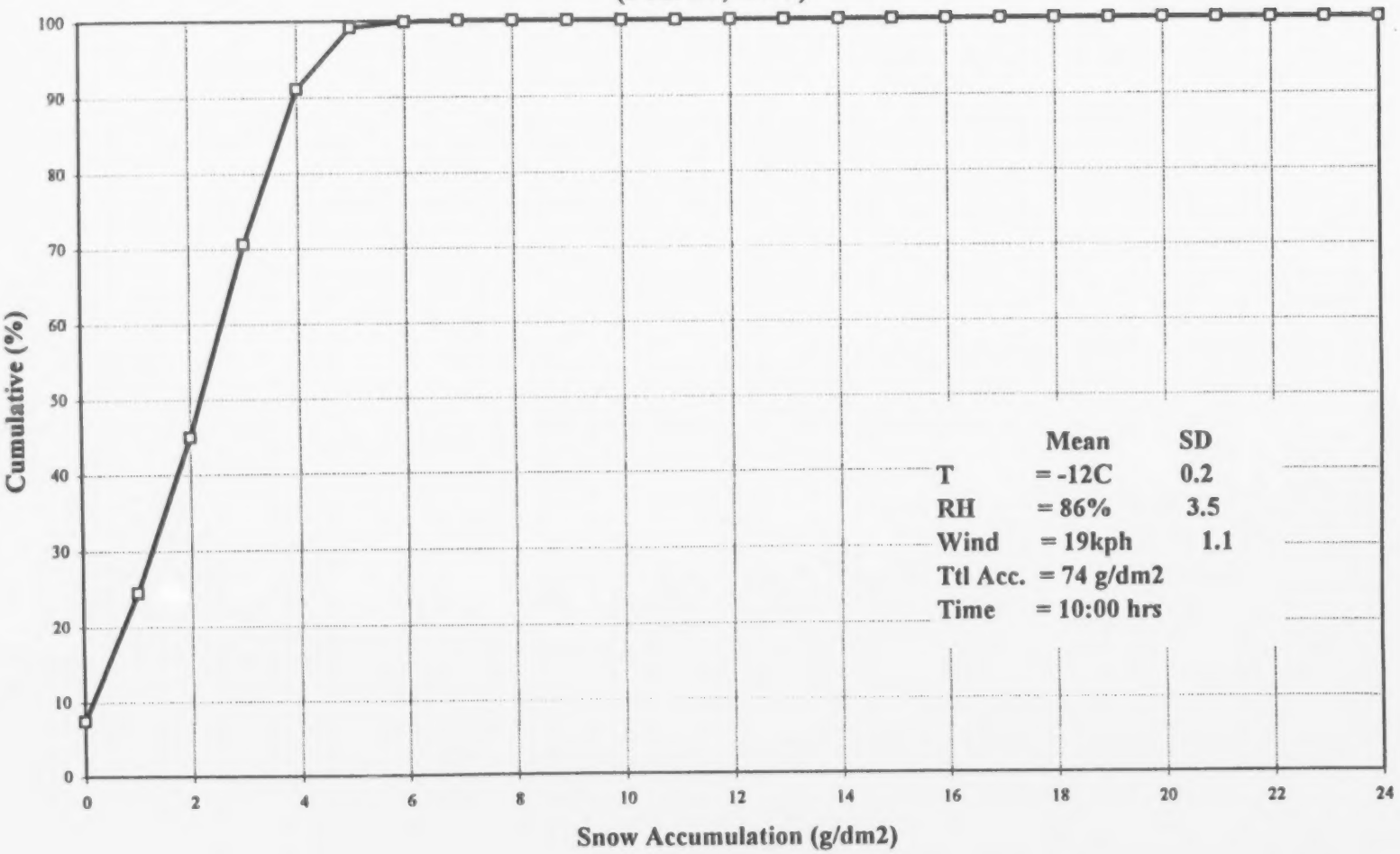
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Feb. 27, 1995)



18/8/95 16:14

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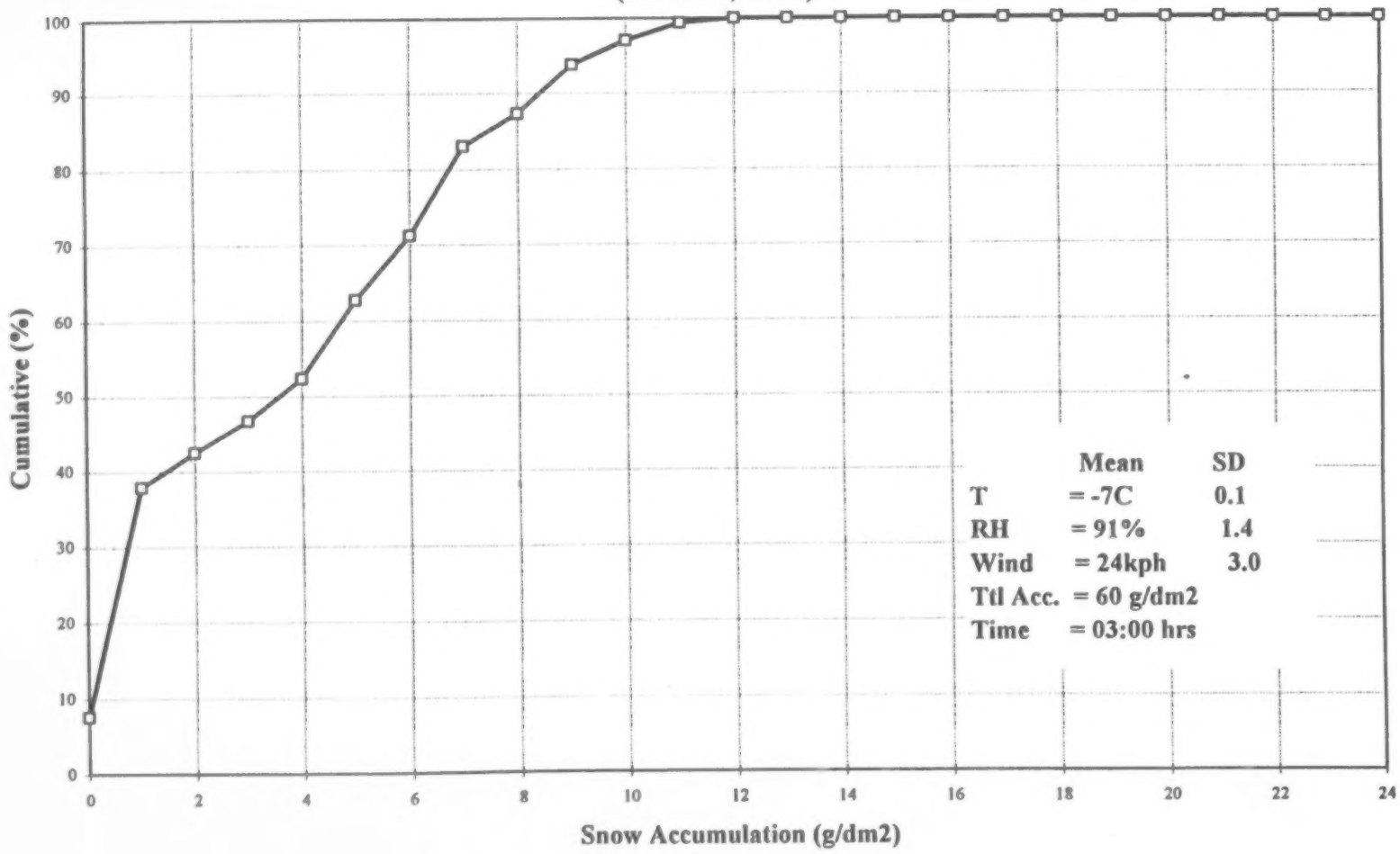
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
(Mar. 06, 1995)



18/8/95 16:03

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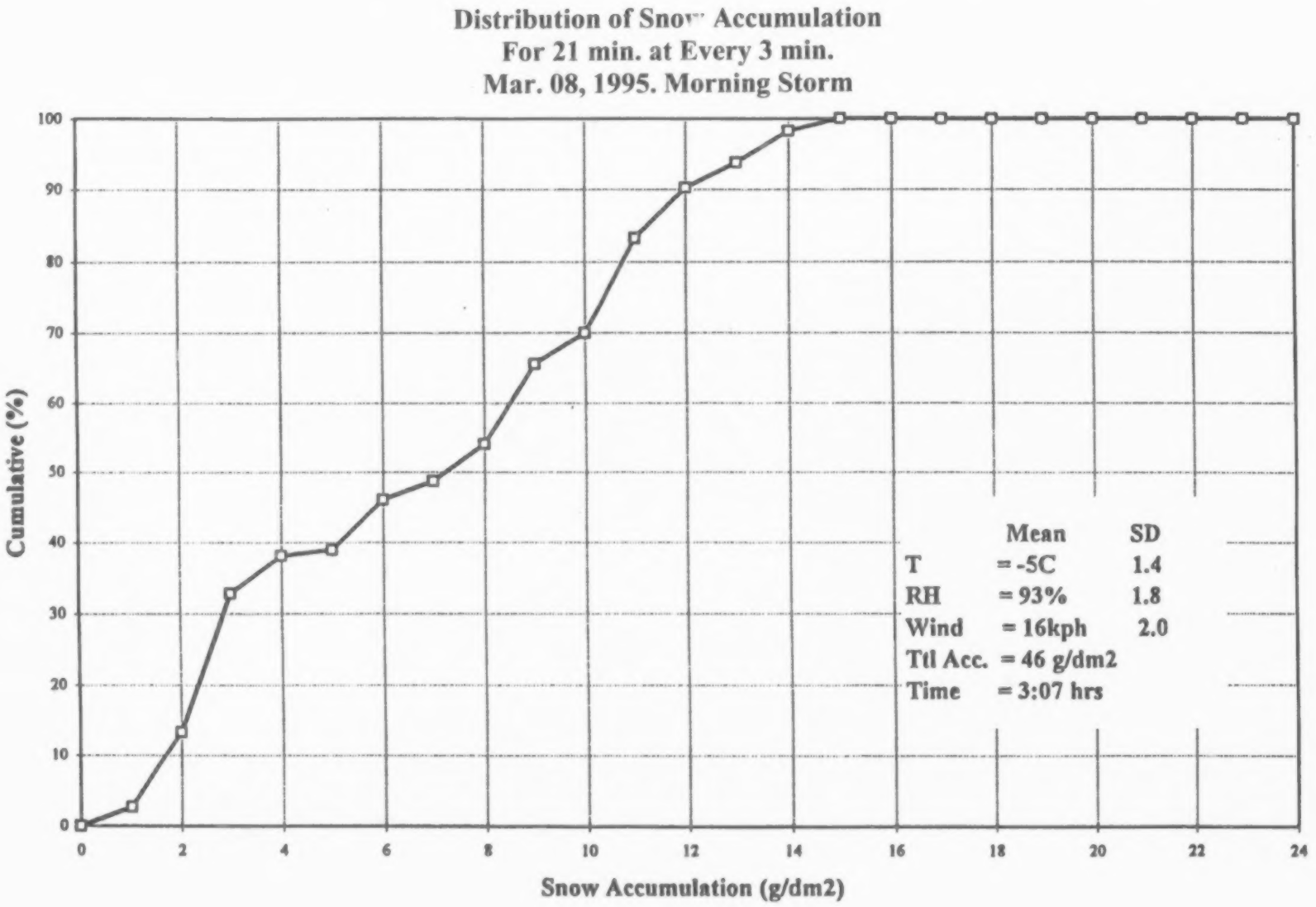
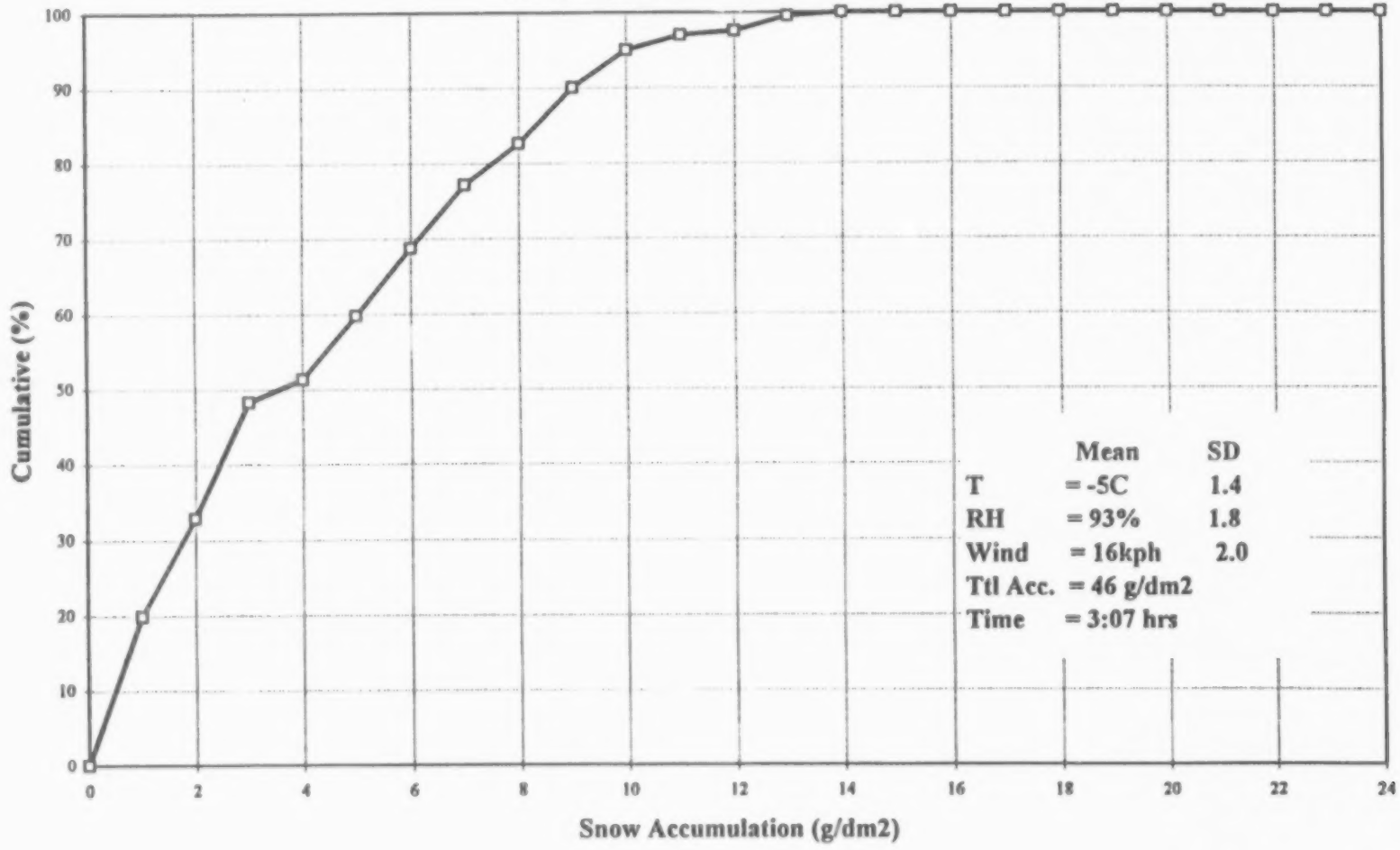


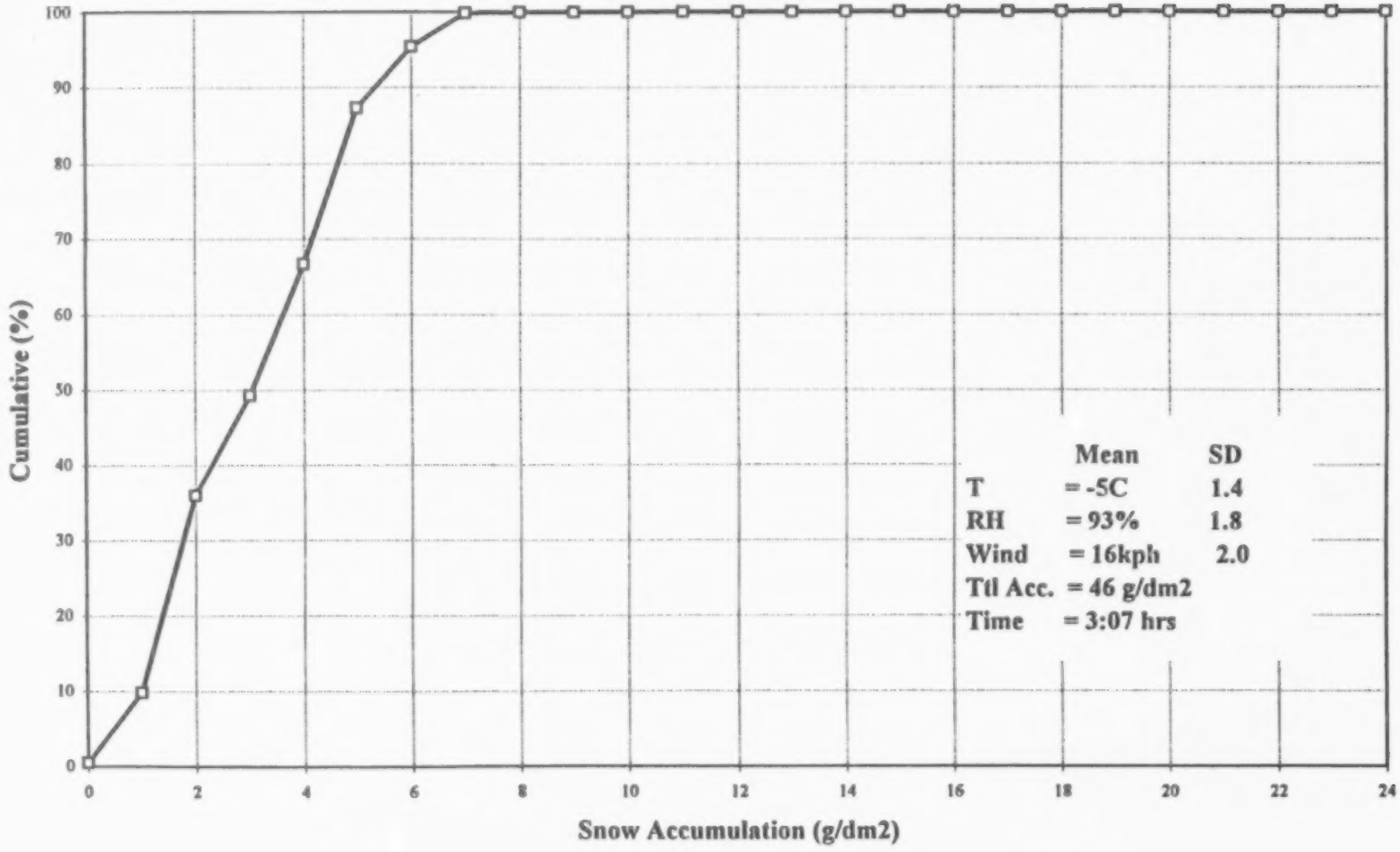
17/8/95 13:43

950308.XLS

Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08, 1995. Afternoon Storm



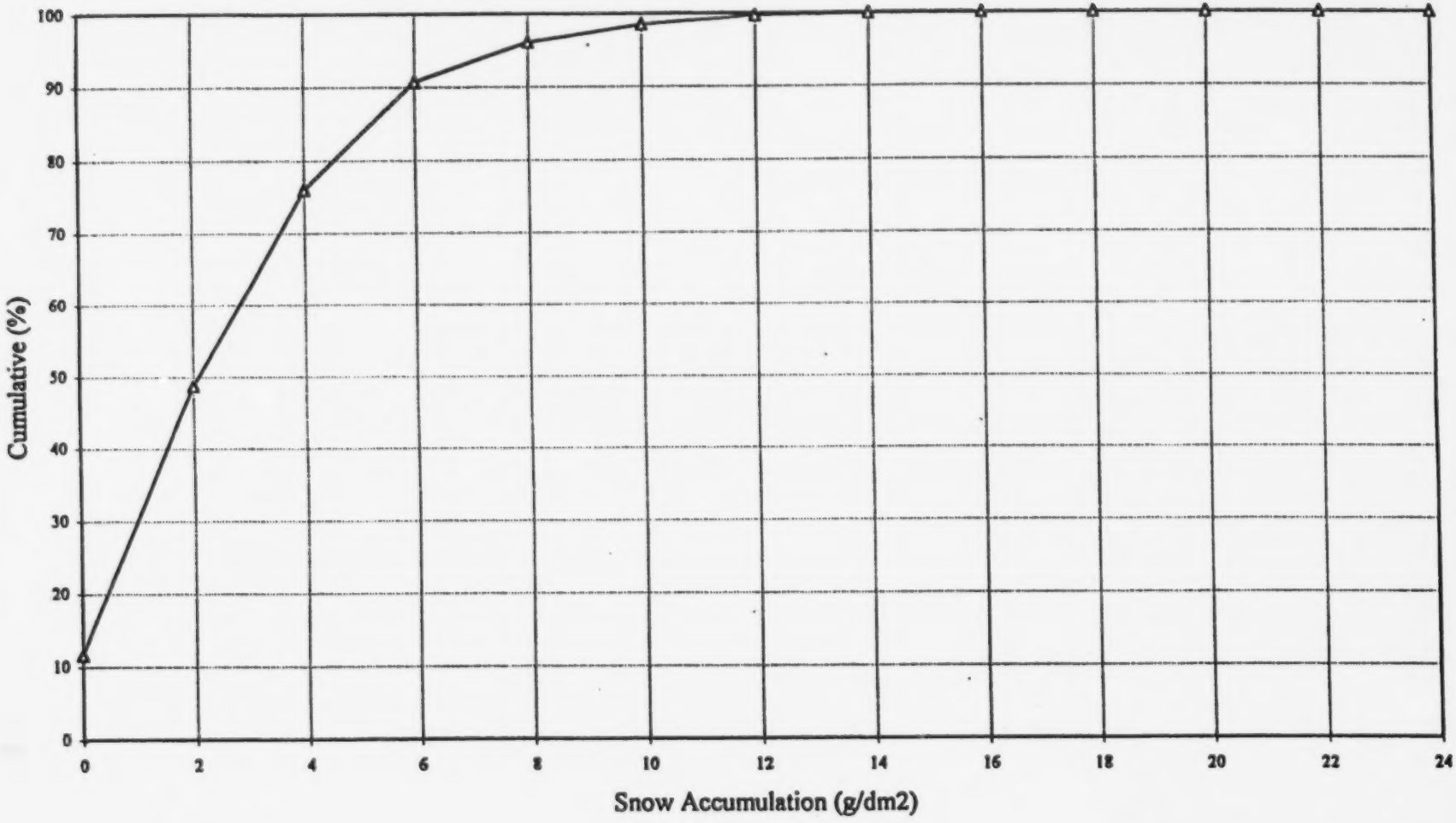
Distribution of Snow Accumulation
For 21 min. at Every 3 min.
Mar. 08-09, 1995



17/8/95 13:43

950308.XLS

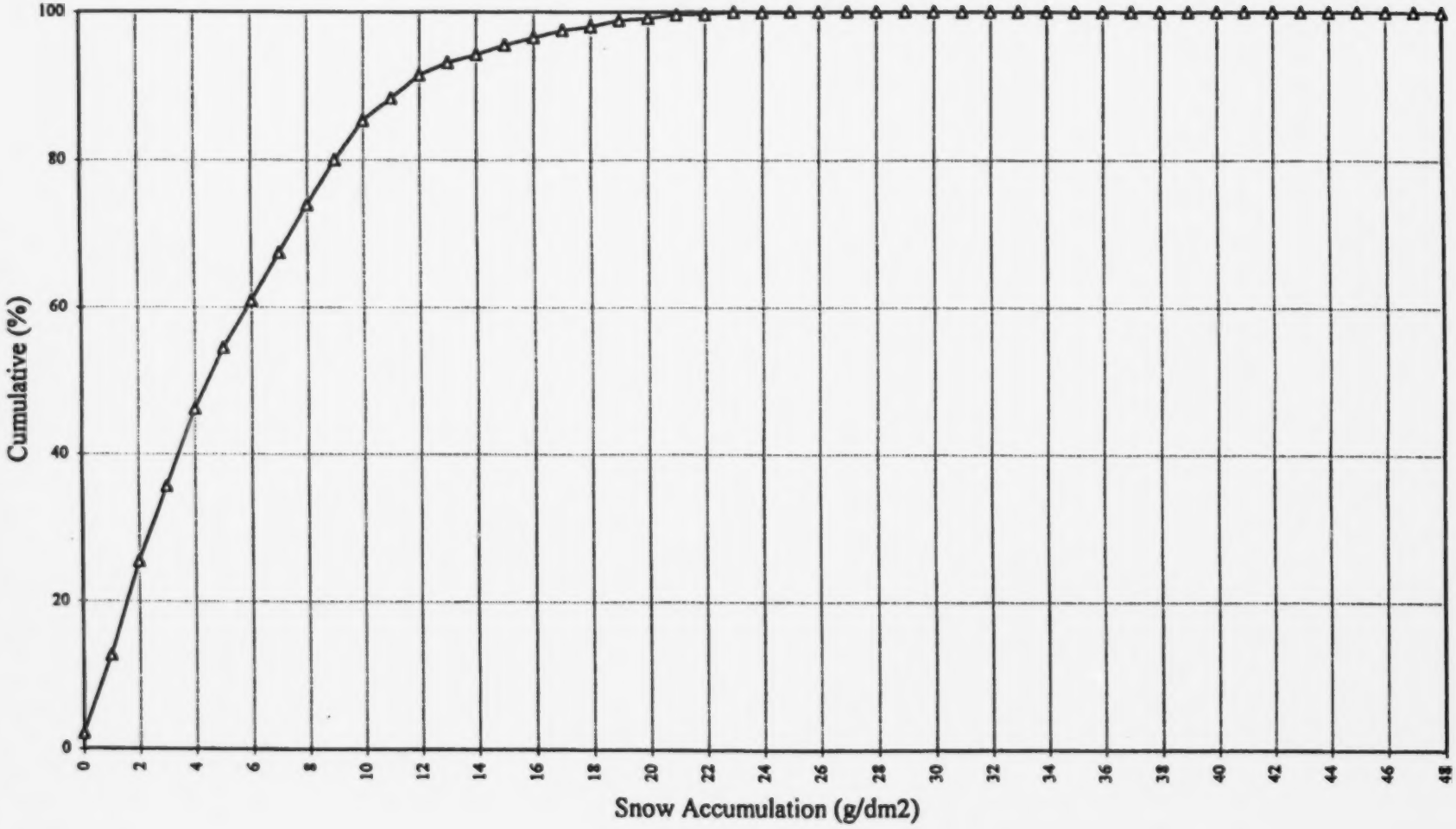
Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1994-1995 Winter



18/8/95 15:25

MHIST95.XLS

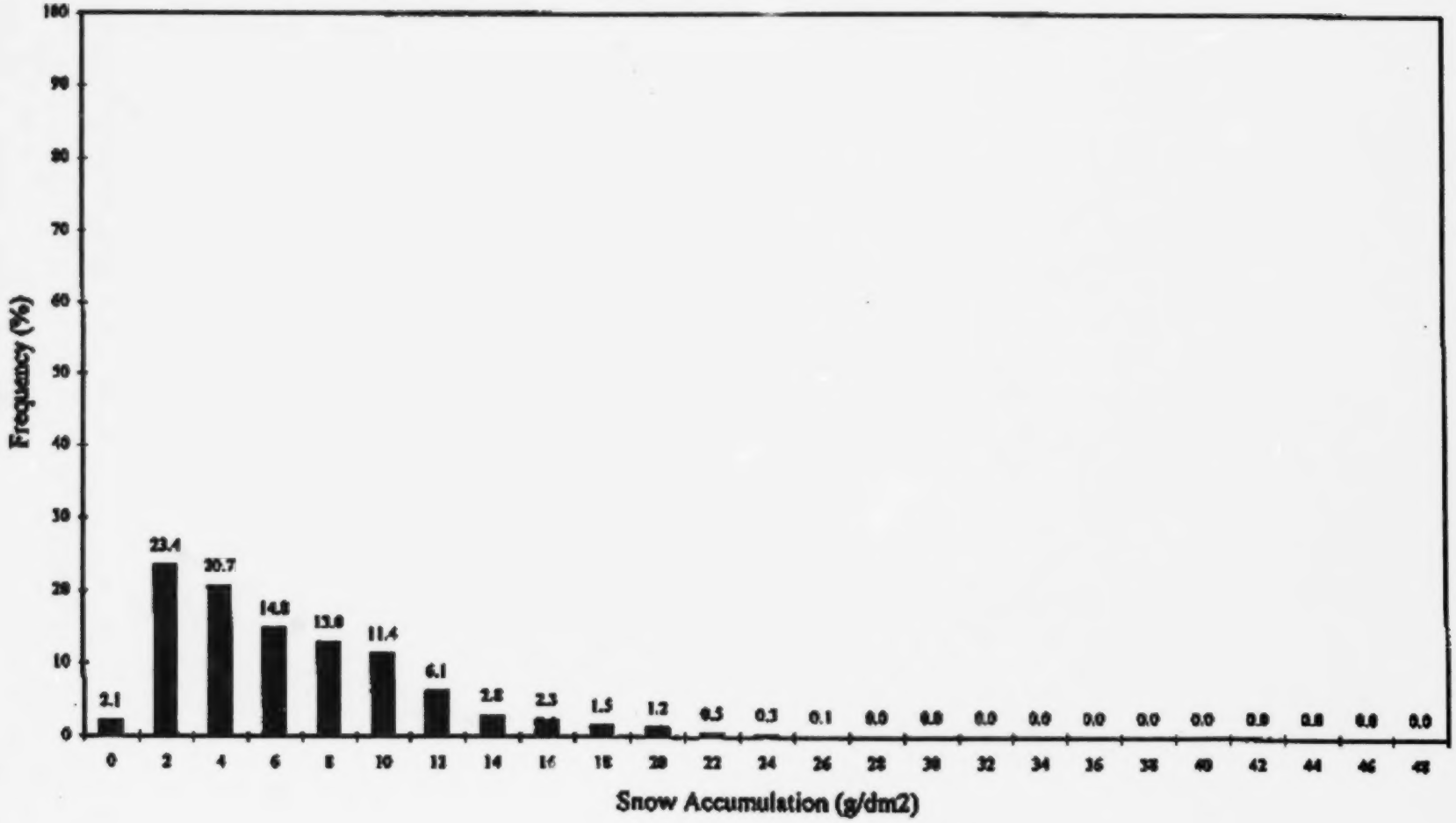
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1994-1995 Winter



18/8/95 14:32

MHIST95.XLS

Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1994-1995 Winter



C-60

18/8/95 14:28

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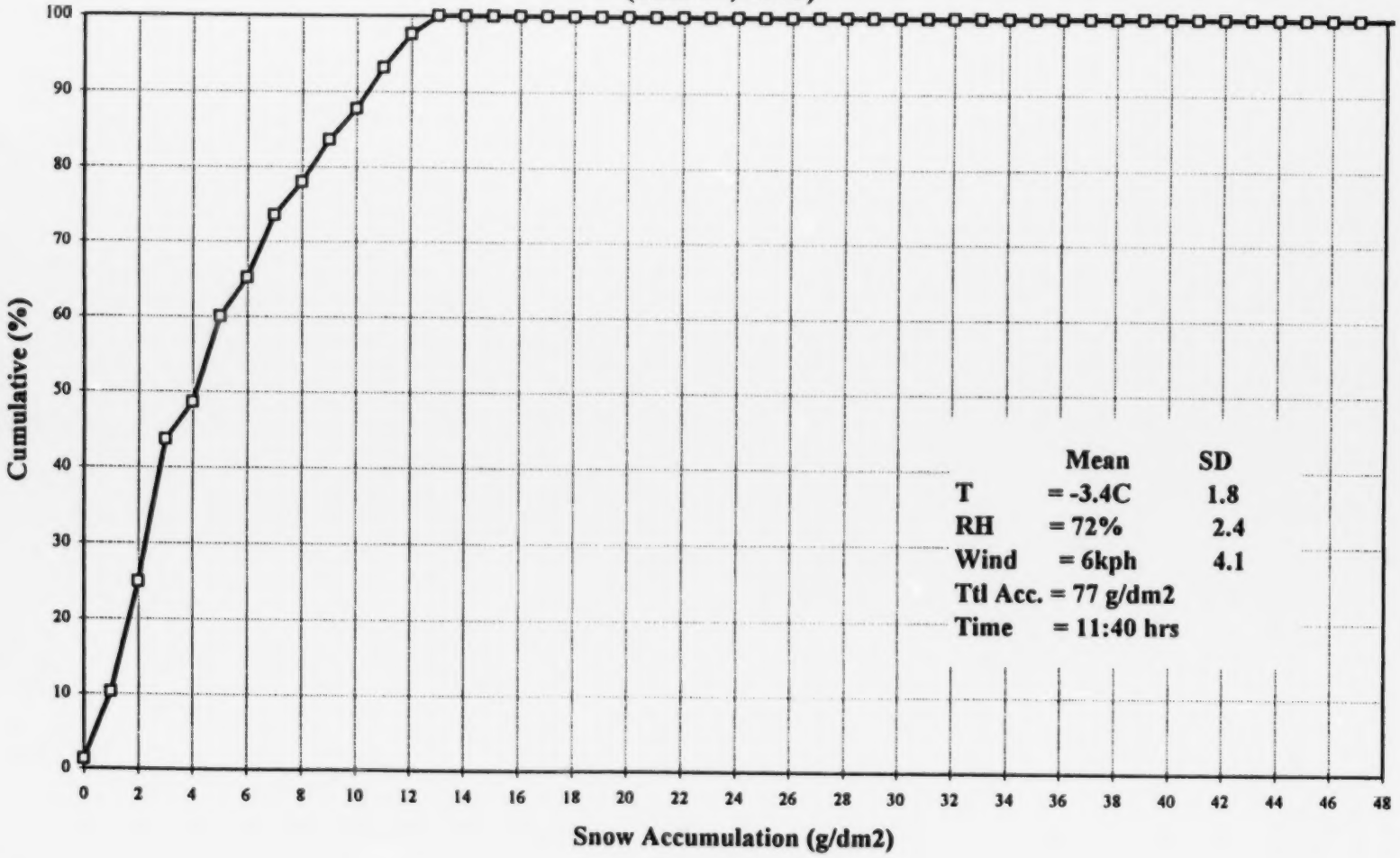
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Jan. 07, 1995)



18/8/95 15:36

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Distribution of Snow Accumulation
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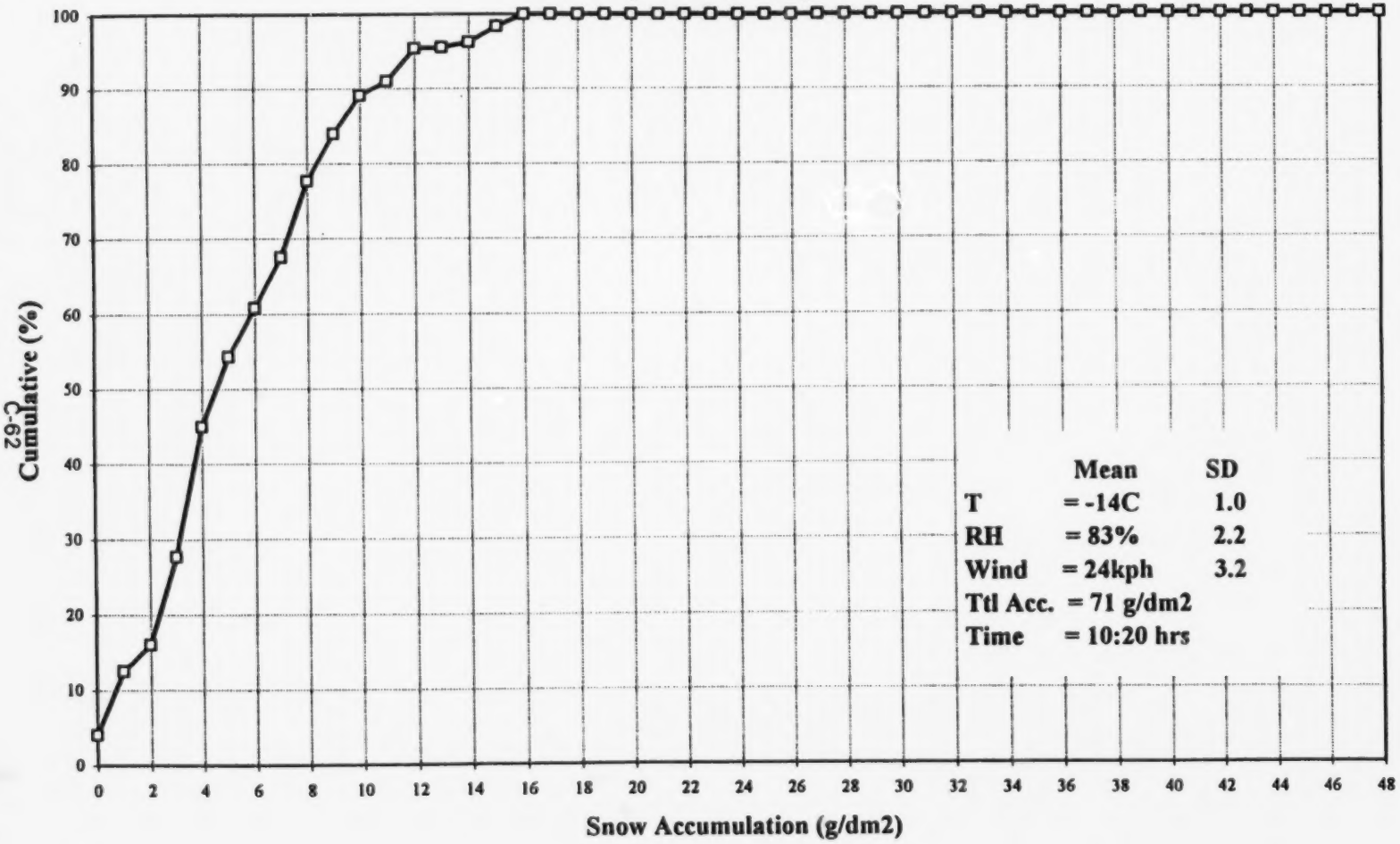
(Jan. 12, 1995)



18/8/95 15:34

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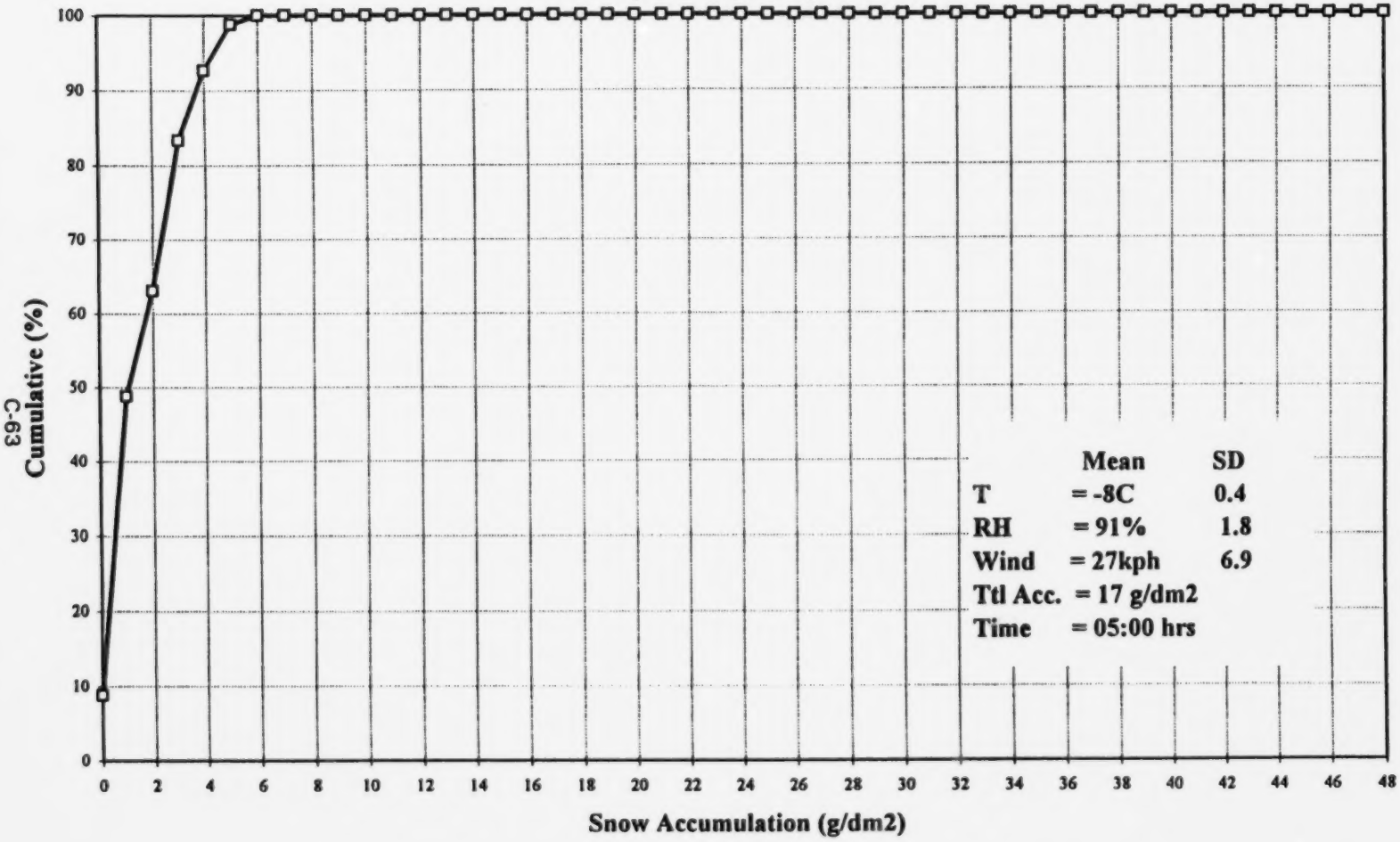
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 04, 1995)



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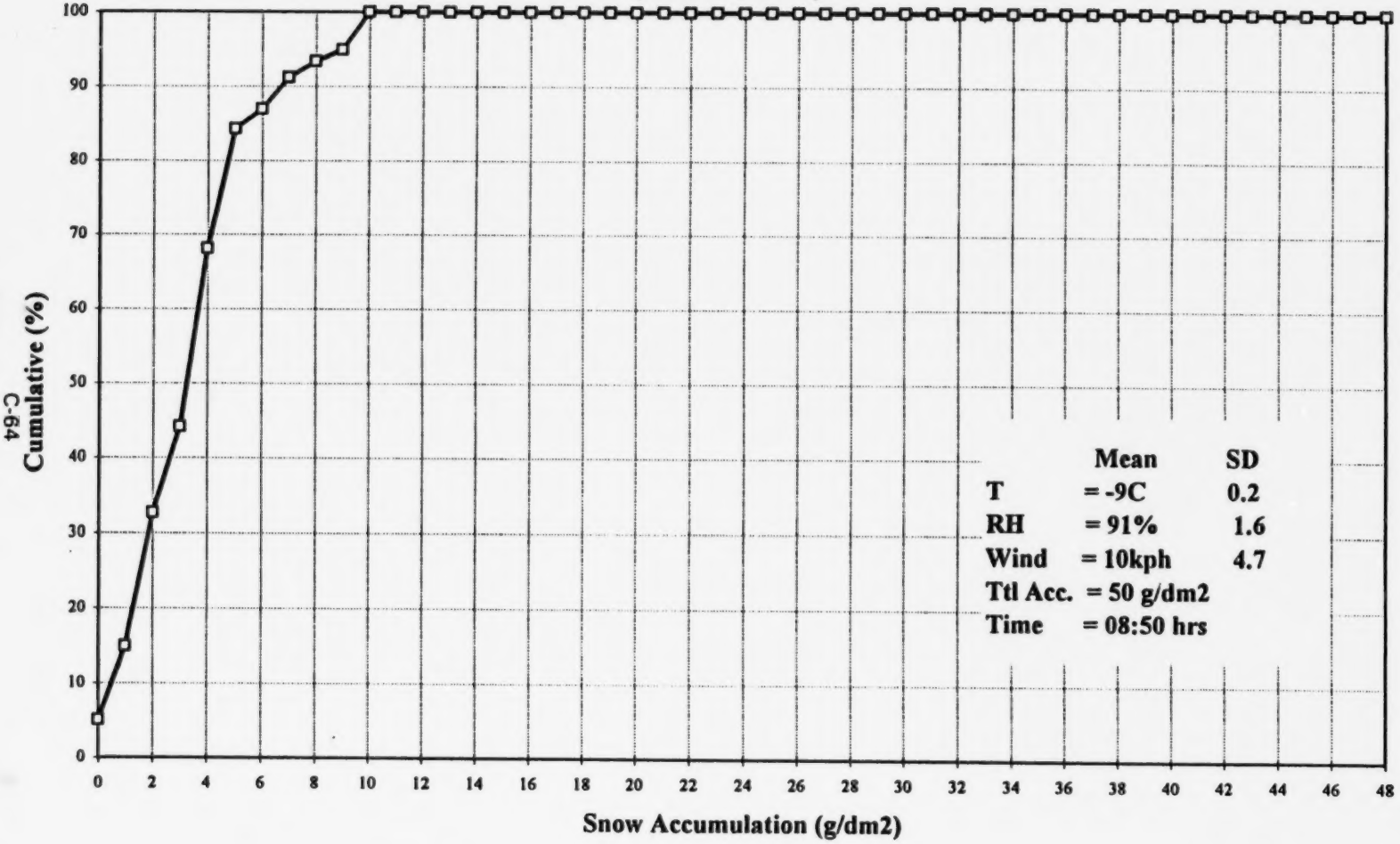
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 11, 1995)



18/8/95 15:49

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Distribution of Snow Accumulation
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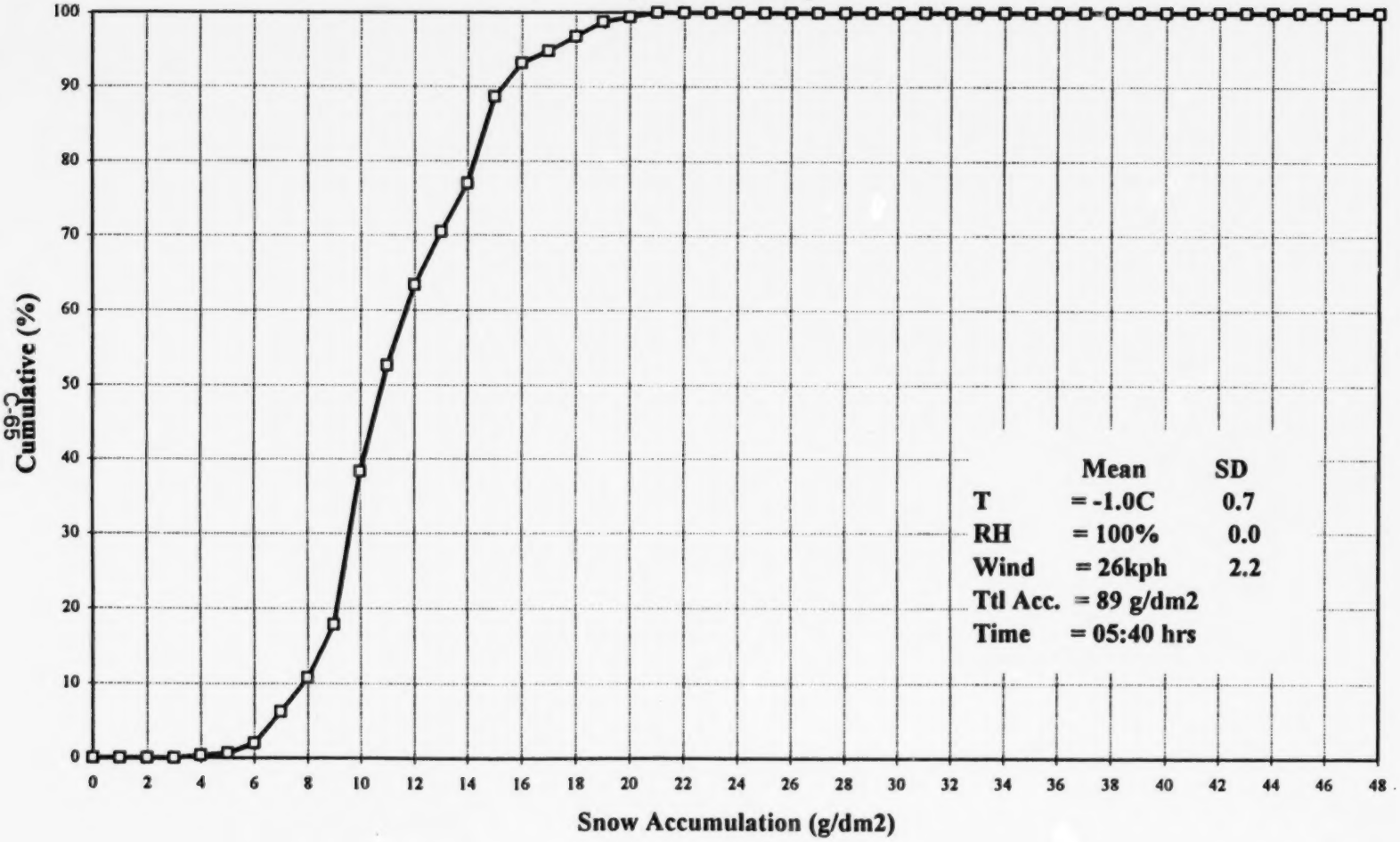
(Feb. 16, 1995)



18/8/95 15:48

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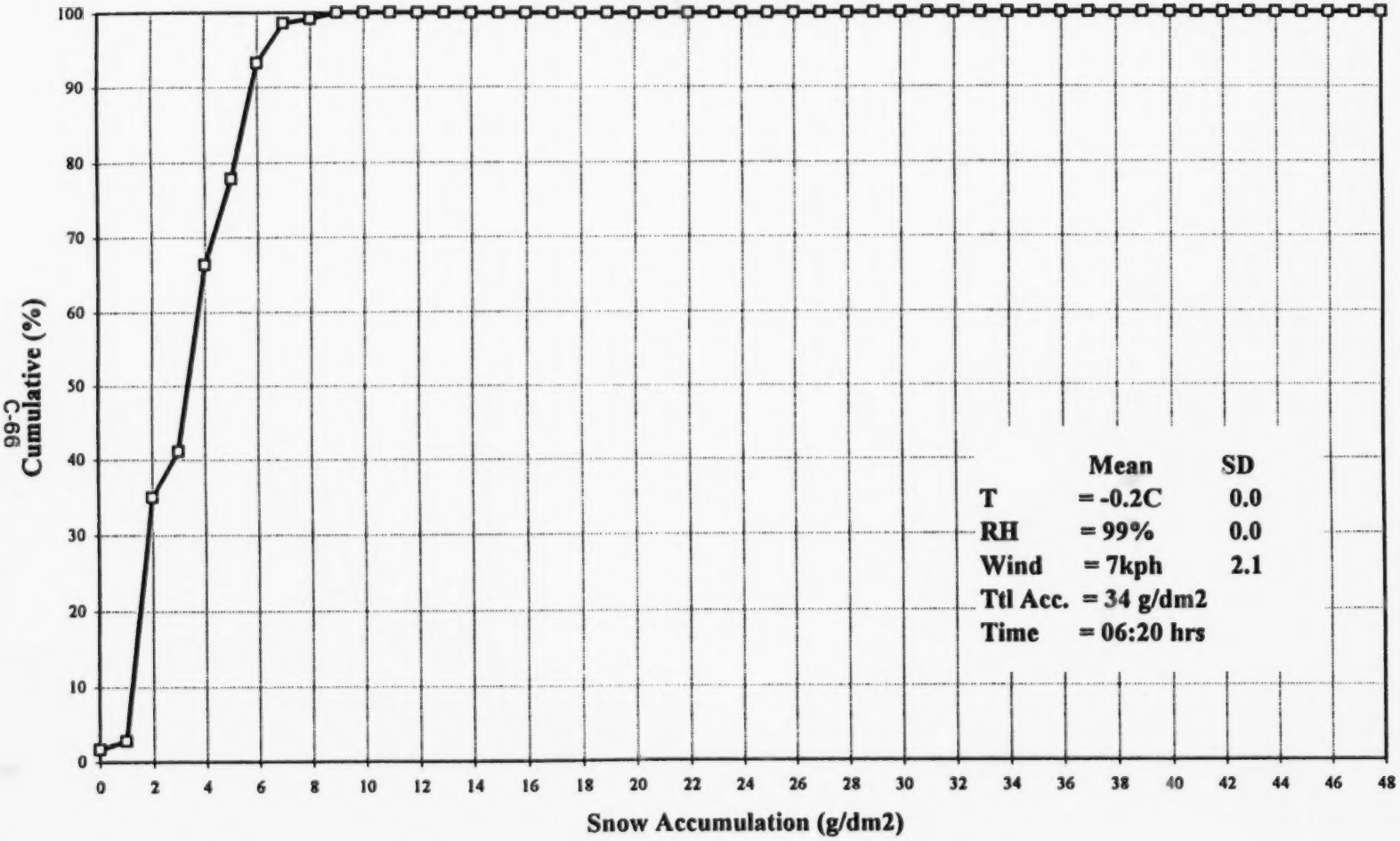
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 24, 1995)



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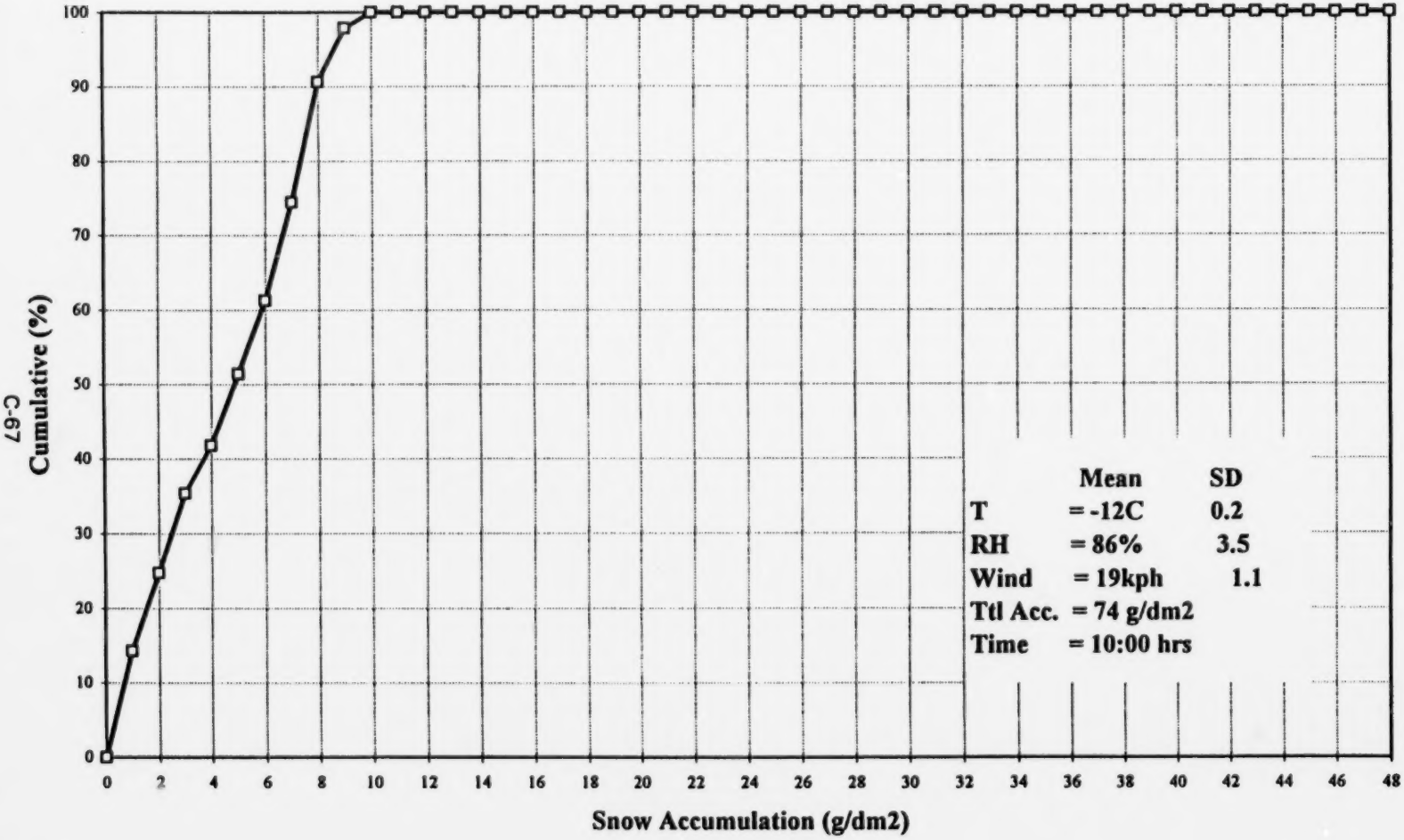
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Feb. 27, 1995)



18/8/95 15:41

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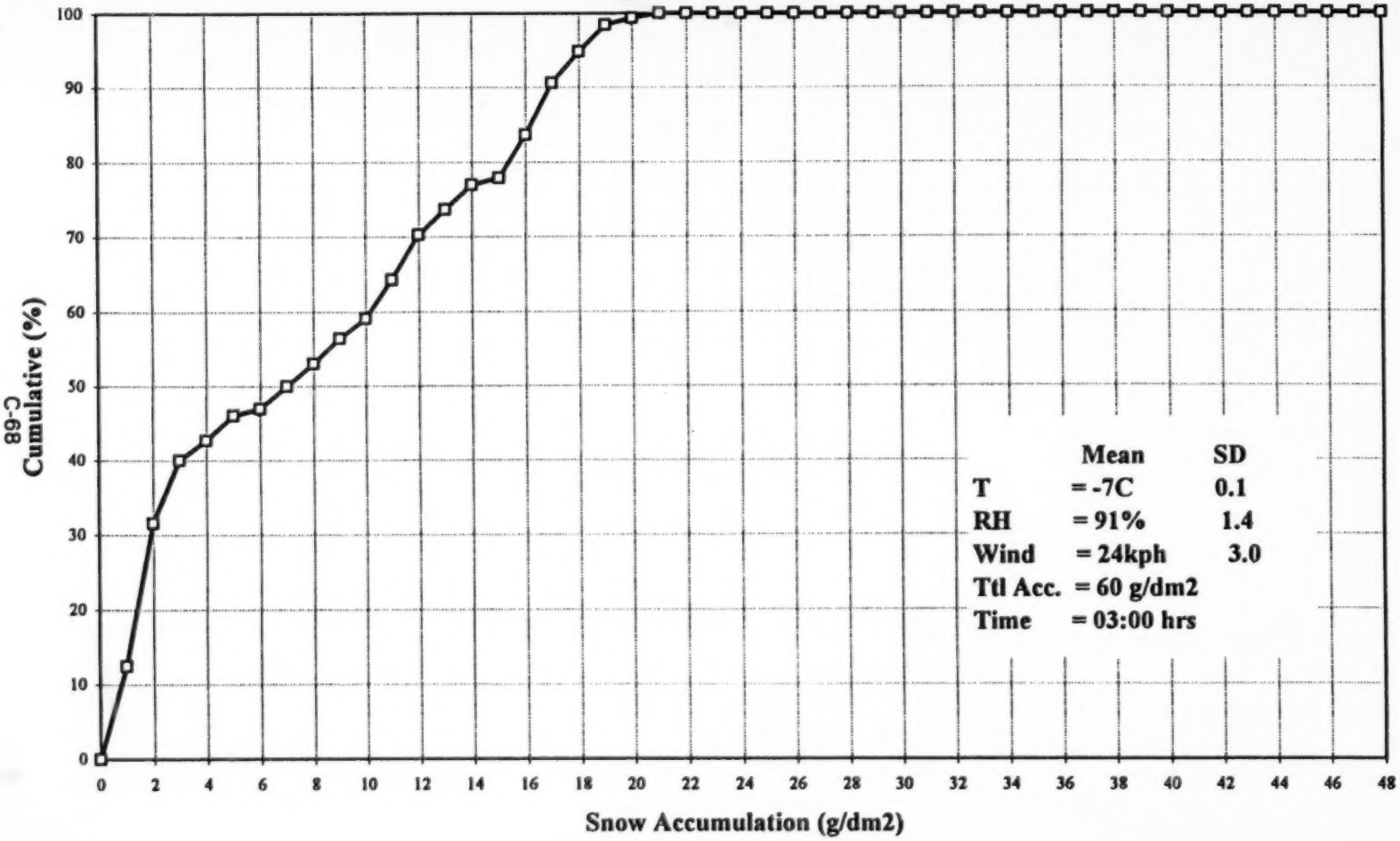
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 06, 1995)

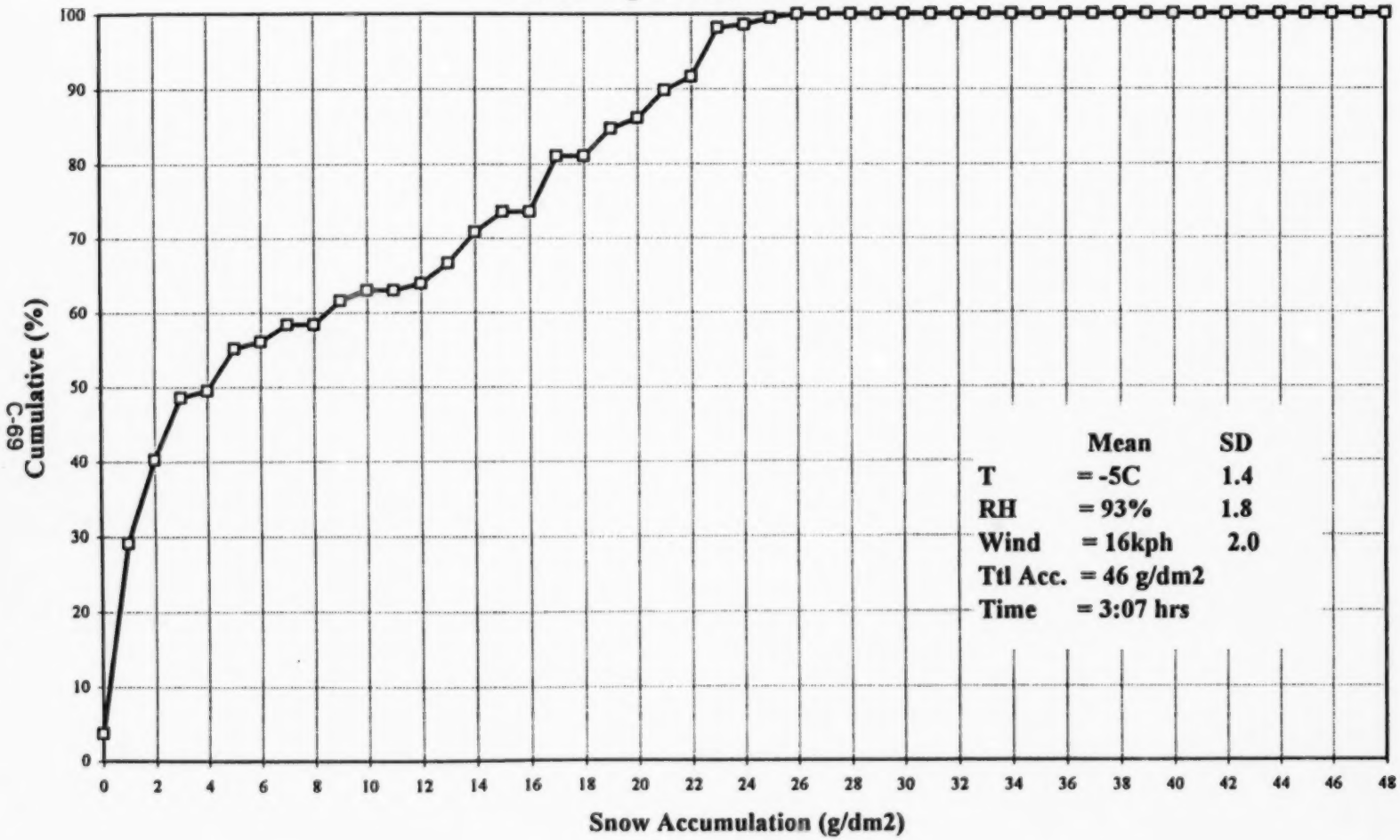


89-C-68

18/8/95 16:03

950306.XLS

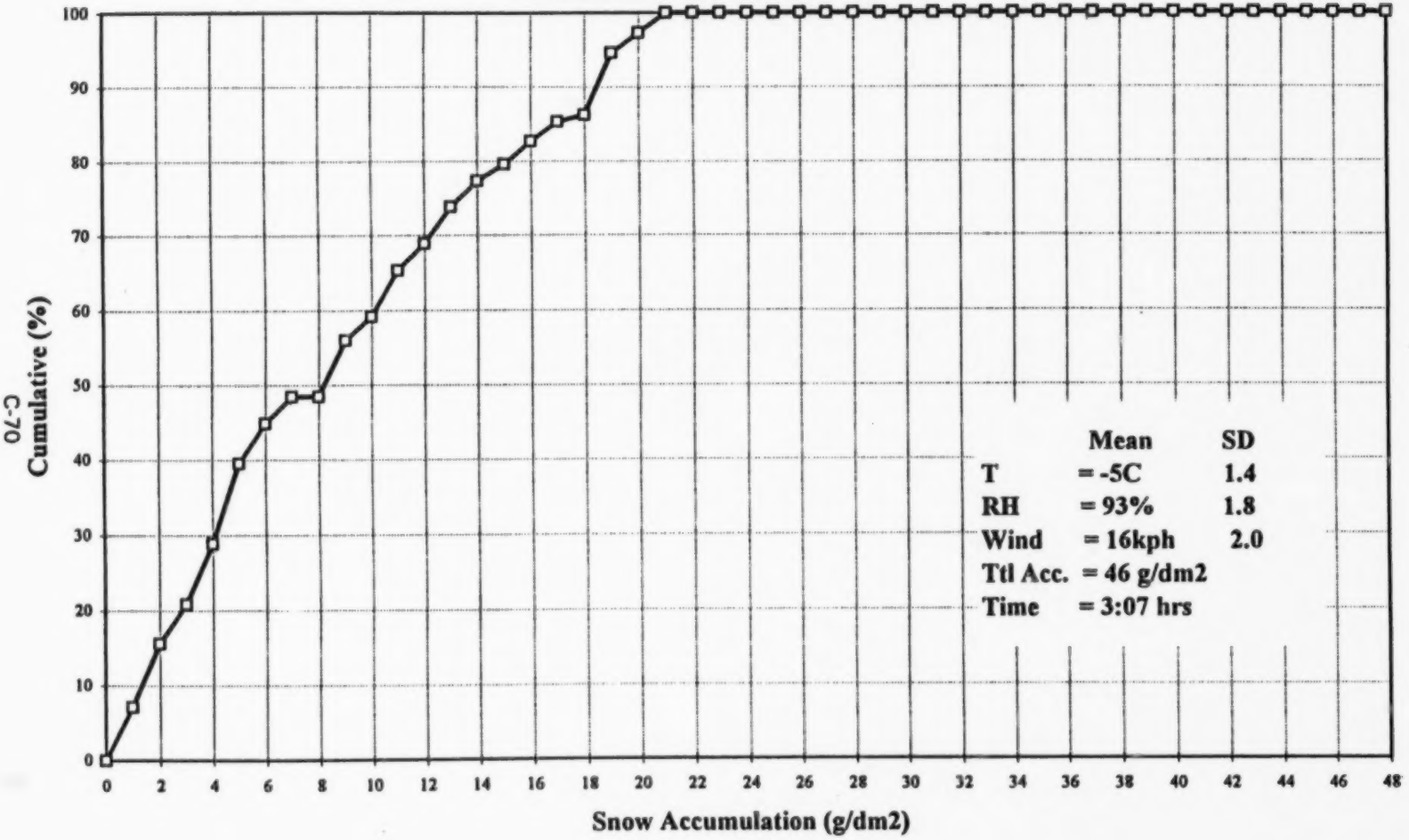
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Morning Storm, Mar. 08, 1995



18/8/95 15:55

950308.XLS

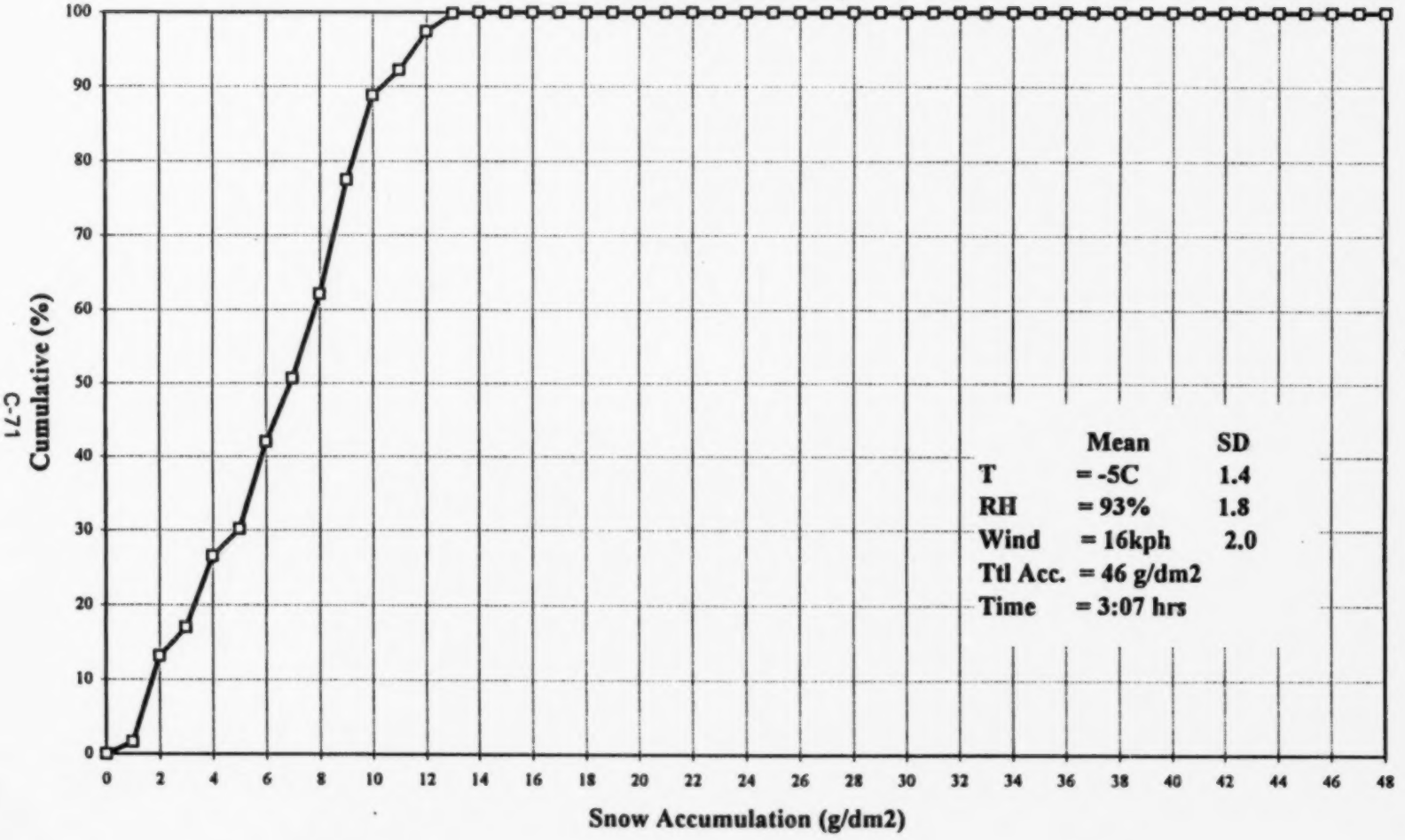
Distribution of Snow Accumulation
For 45 min. at Every 3 min.
Afternoon Storm, Mar. 08, 1995



18/8/95 15:55

950308.XLS

Distribution of Snow Accumulation
For 45 min. at Every 3 min.
(Mar. 08-09, 1995)

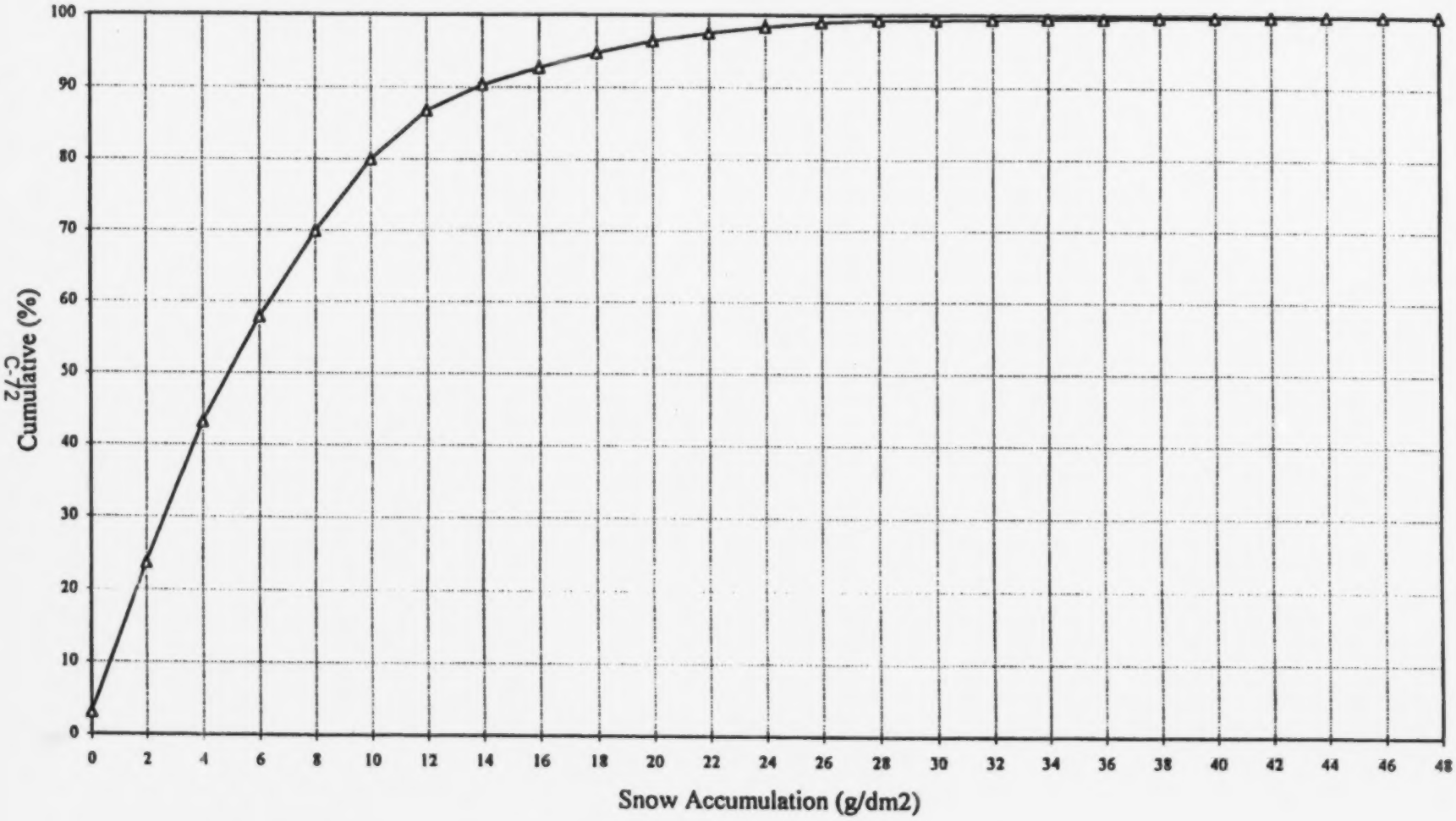


C-71

18/8/95 15:55

950308.XLS

Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



18/8/95 12:09

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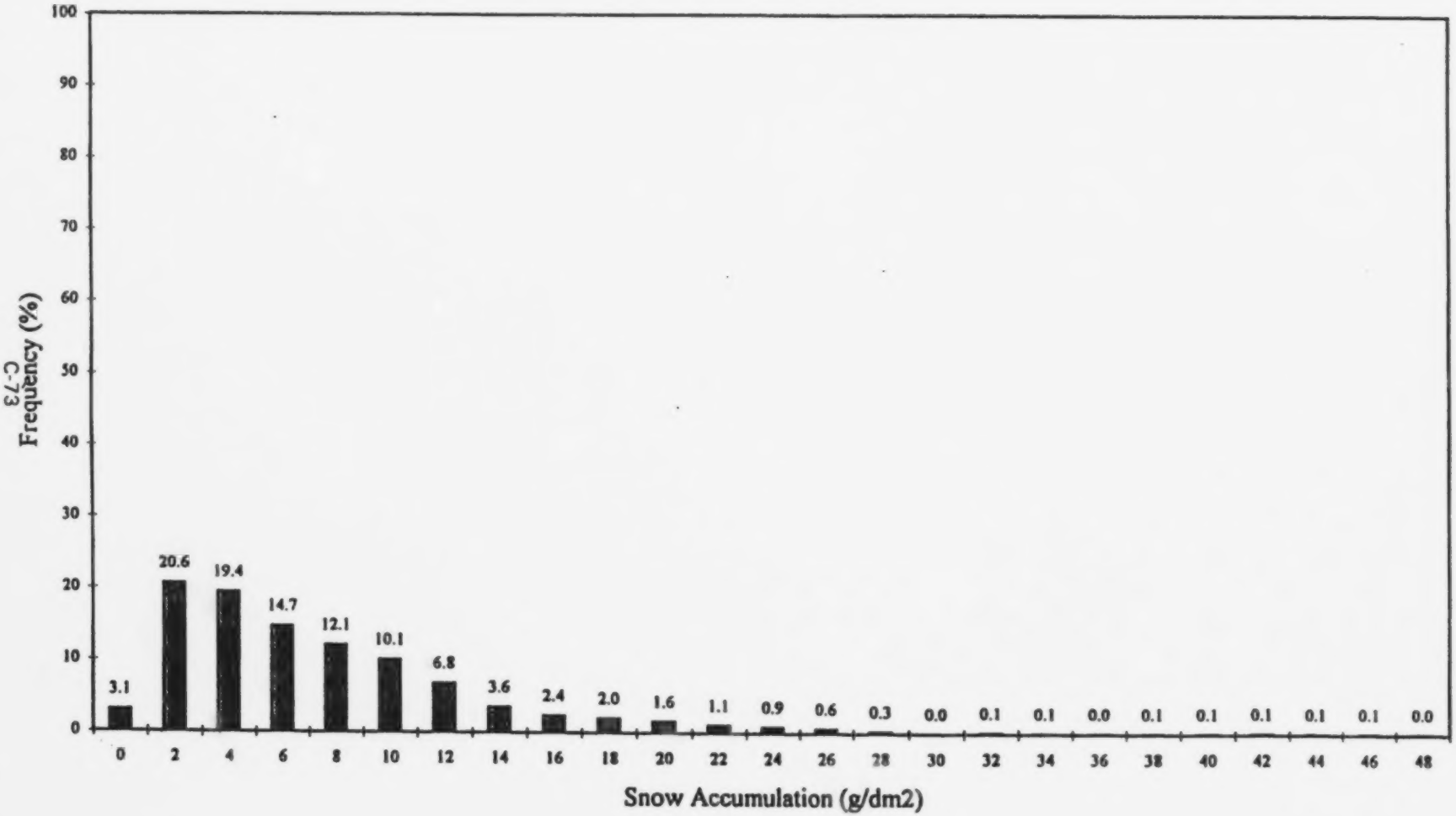
Histogram for Snow Accumulation
For 45 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



18/8/95 12:10

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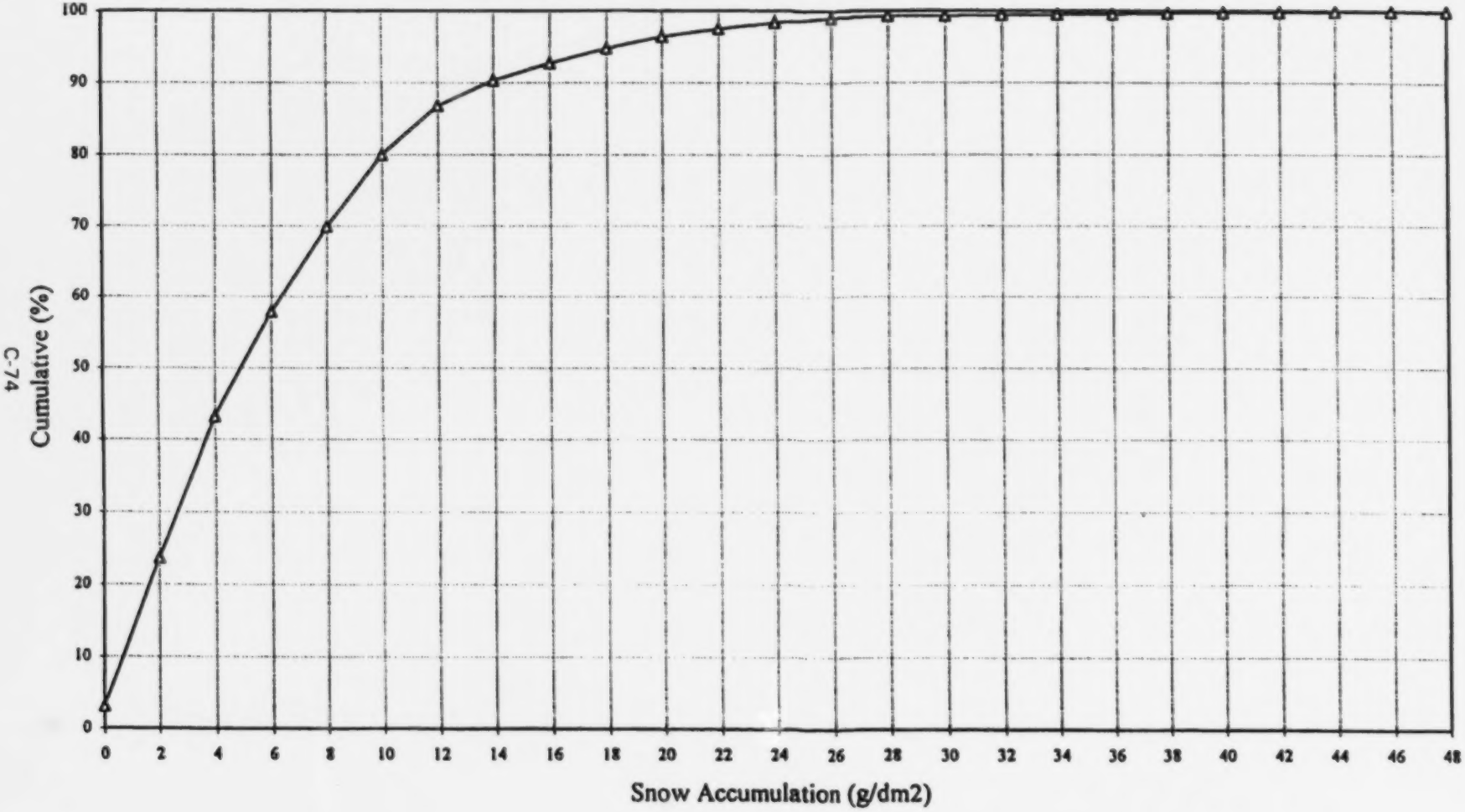
Distribution for Snow Accumulation
For 45 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



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Histogram for Snow Accumulation
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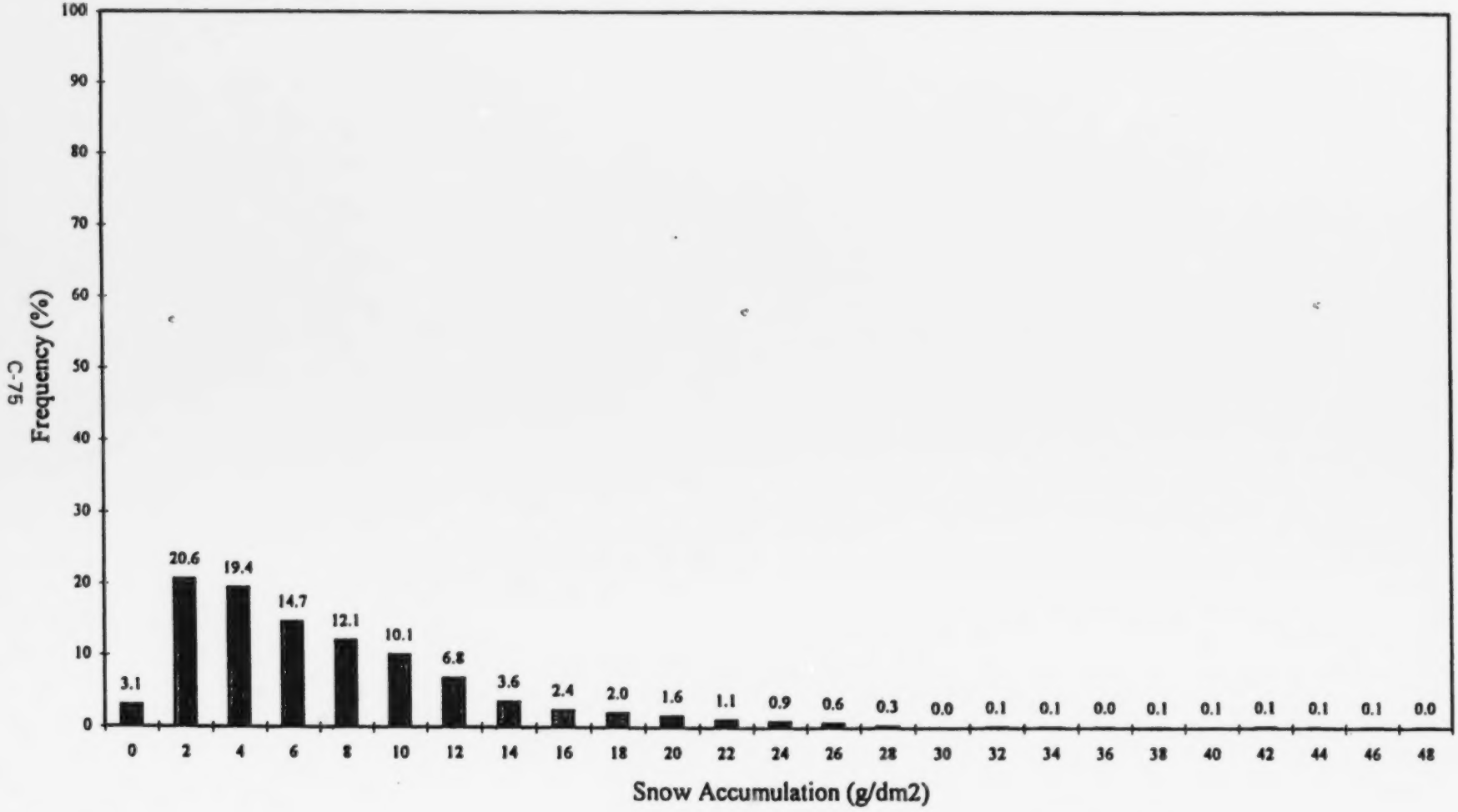
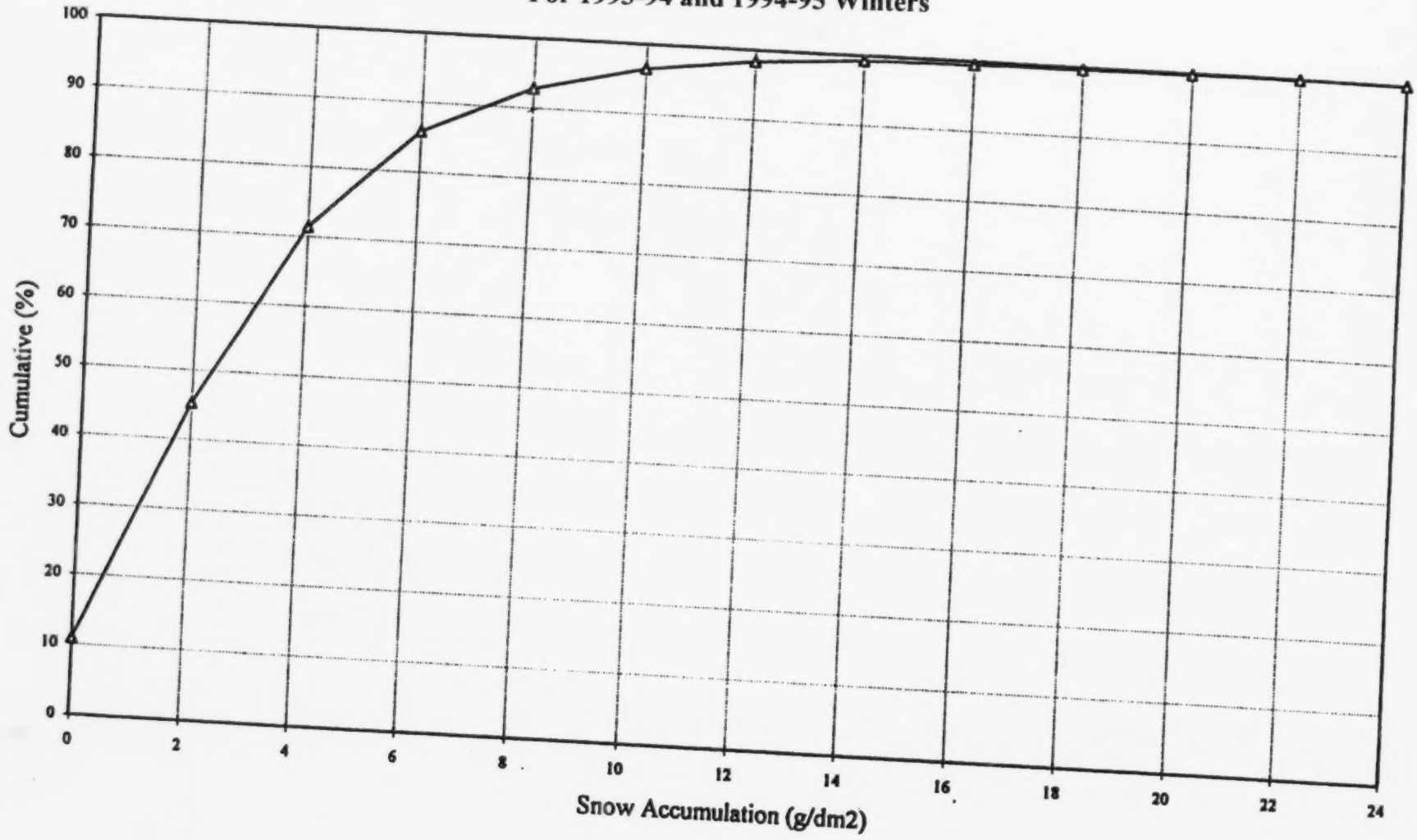
For 1993-94 and 1994-95 Winters



18/8/95 12:10

MHIST95.XLS

Distribution for Snow Accumulation
For 21 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



C-76

17/8/95 13:55

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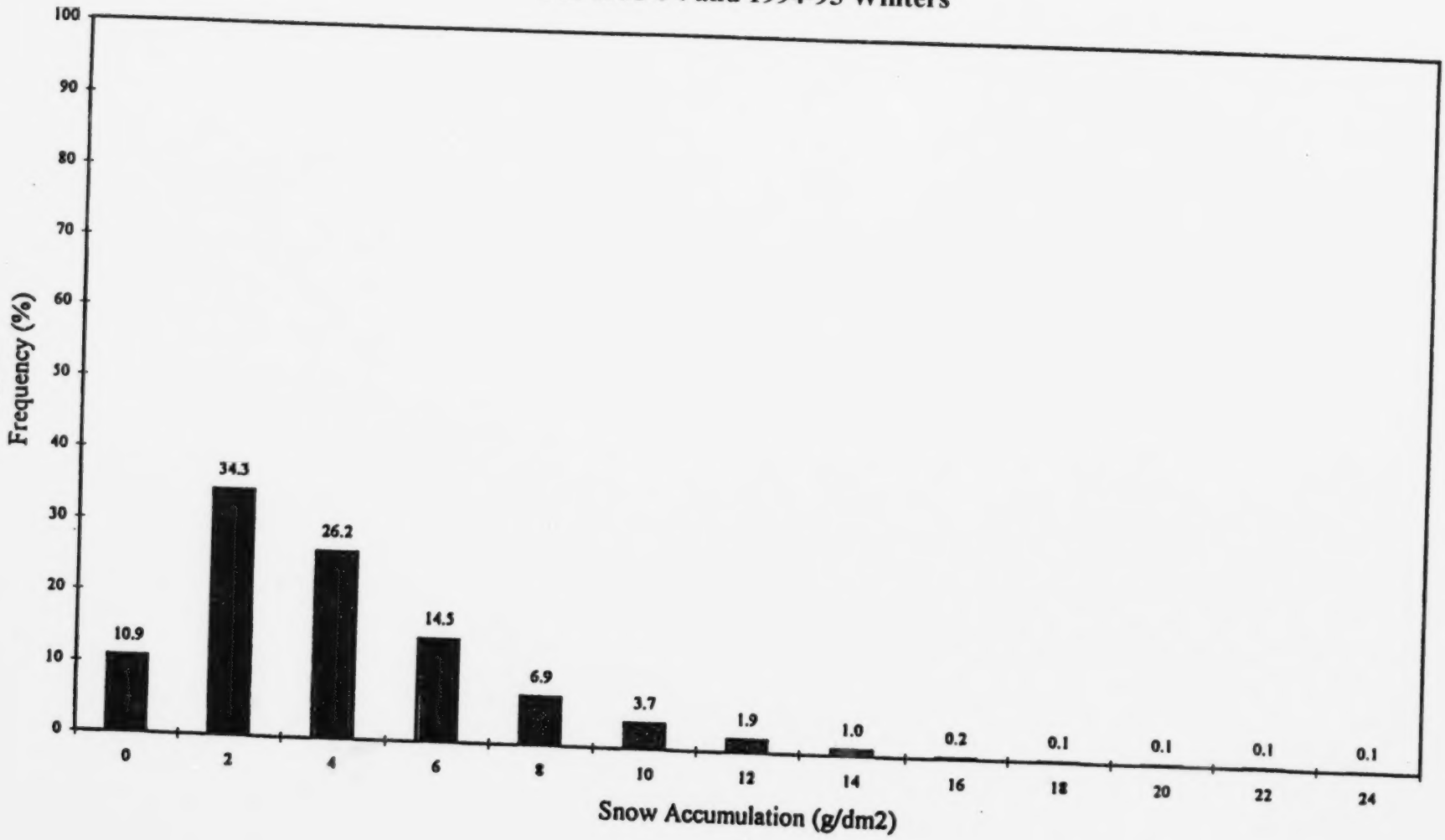
Histogram for Snow Accumulation
For 21 min. at Every 3 min.
For 1993-94 and 1994-95 Winters



C-77

17/8/95 12:10

MHIST95.XLS

APPENDIX D

AES STUDY

FREQUENCY OF OCCURRENCE OF WATER EQUIVALENT PRECIPITATION RATES AS A FUNCTION OF AVERAGING TIME, TEMPERATURE, AND TYPE

Draft

Frequency of Occurrence of Water Equivalent Precipitation Rates as a function of Averaging Time, Temperature and Type

1.0 Introduction

The proposed Holdover Time Tables give the failure time of various types of anti-icing fluids for different precipitation types, temperatures and water equivalent precipitation rates. In order to specify realistic precipitation rates in these tables, the cumulative probability distribution of rates averaged over the different holdover times must be determined. This report presents these distributions using data collected from an experimental site situated at Pearson International Airport established in 1995 with Dryden Commission Implementation Project funding to study nowcasting of on-ground aircraft icing.

2.0 Precipitation rate measurement

There is no internationally recognized "reference" instrumentation for measuring precipitation rate. Standard automated weighing gauges do not have sufficient resolution to report rate with the minutely time resolution required. Meteorological observers report an "intensity" of precipitation in four categories: very light, light, moderate and heavy. This is based on a broad classification of rate which is inadequate for the nowcasting of the holdover times. The observer also makes climatological measurements of accumulated amounts of precipitation every six hours. In the case of frozen precipitation the amount reported is the "water equivalent" of the melted precipitation.

One of the objectives of the experiment at Pearson International Airport (YYZ) was to evaluate the performance of new technologies designed to measure precipitation rates in both liquid and frozen phases with minutely reporting resolution. Several sensors were evaluated and it was determined that a small Doppler radar called the Precipitation Occurrence Sensor

System (POSS) agreed the best with the observed 6-hourly accumulated precipitation amounts. This study will be reported on elsewhere.

2.1 POSS

The Precipitation Occurrence Sensor System is a small Doppler X-band radar designed by the Atmospheric Environment Service as a present weather sensor for its automatic weather observing stations. It is commercially manufactured under licence by Andrew Antenna, Canada. The sensor reports every minute the occurrence, type, intensity, rate and accumulation of precipitation.

The precipitation rate is estimated using the same method as is done with large-scale precipitation radars. The method, referred to as the "Z-R" method, measures the radar reflectivity factor (Z) to estimate the precipitation rate (R).

3.0 Analysis

The water equivalent precipitation rate is reported by the POSS every minute. These rates are averaged using a "sliding box car " for the three specified periods used in the holdover time tables: 6, 20 and 35 minutes. The data is then classified into three precipitation types as reported by the meteorological observer at the site: snow, freezing rain of light intensity and freezing drizzle. In the case of mixed precipitation types the data is included in a class if that type is reported as one of the mixed types. The data is further classified into the four temperature ranges proposed in the Holdover time tables: 0 to -3C, -3 to -7C, -7 to -14C and -14 to -25C.

The frequency of occurrence with respect to the average water equivalent precipitation rate is determined. The average is included in these statistics only if at least half the minutes have non-zero precipitation rates. In addition, if there is missing data, then at least have the averaging time must have valid measurements. This approach deliberately excludes intermittent precipitation from biasing the percentile statistics.

4.0 Results

The results are presented graphically in plots of cumulative probability versus precipitation rate averaged over a specified period. The cumulative probability at a specific precipitation rate is the percentage of the dataset with precipitation rates less than that rate. There is one graph for each combination of averaging time and temperature (see Figures below).

Each graph displays a curve for each of the three precipitation classes.

In snow, the 95% percentile of the water equivalent precipitation rate averaged over 6 minutes decreases with temperature from about 1.6 mm/h at 0 to -3C to 0.8 mm/h at -14 to -25C. Similar results were found for the other averaging times.

The 95% percentile for light freezing rain is 4.3 mm/h for a 6-minute averaging time in the temperature range 0 to -3C. Light freezing rain did not occur below -3C.

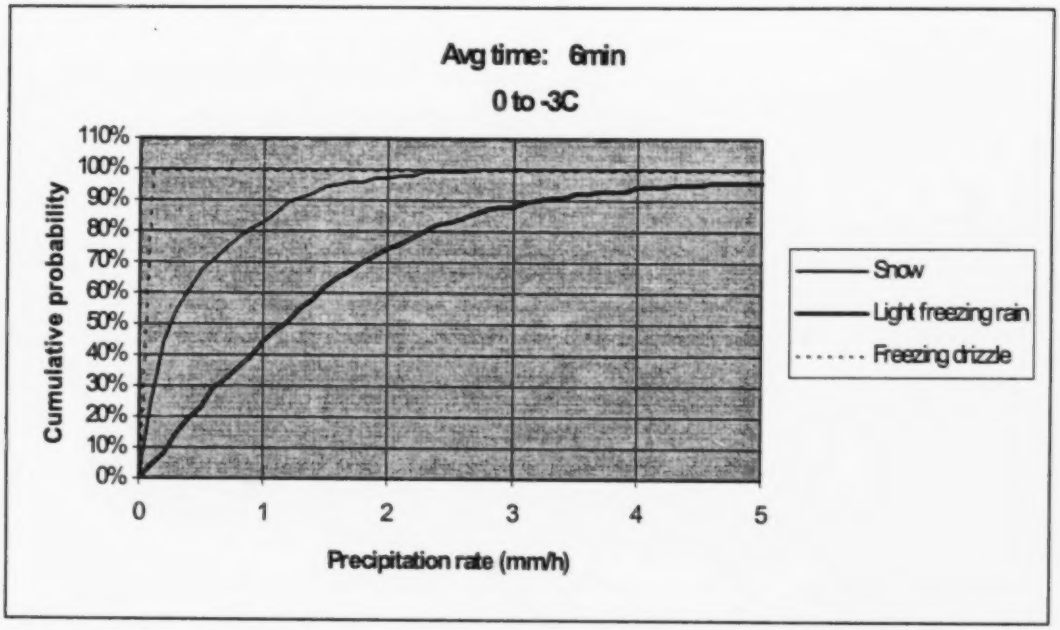
There were few occurrences of freezing drizzle from this location during the experimental period.

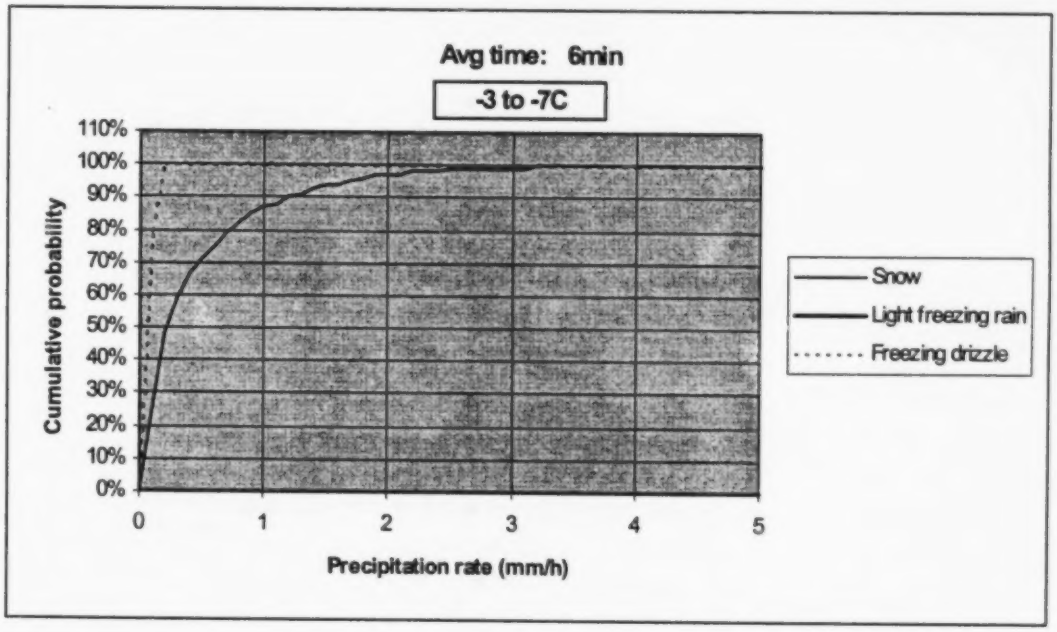
A second set of graphs compares the effect of changing the averaging time for calculating the precipitation rate for snow and freezing rain of light intensity. The cumulative probability curves in snow for the temperature range 0 to -3C are very similar, with the 95% percentile constant at 1.6 mm/h.

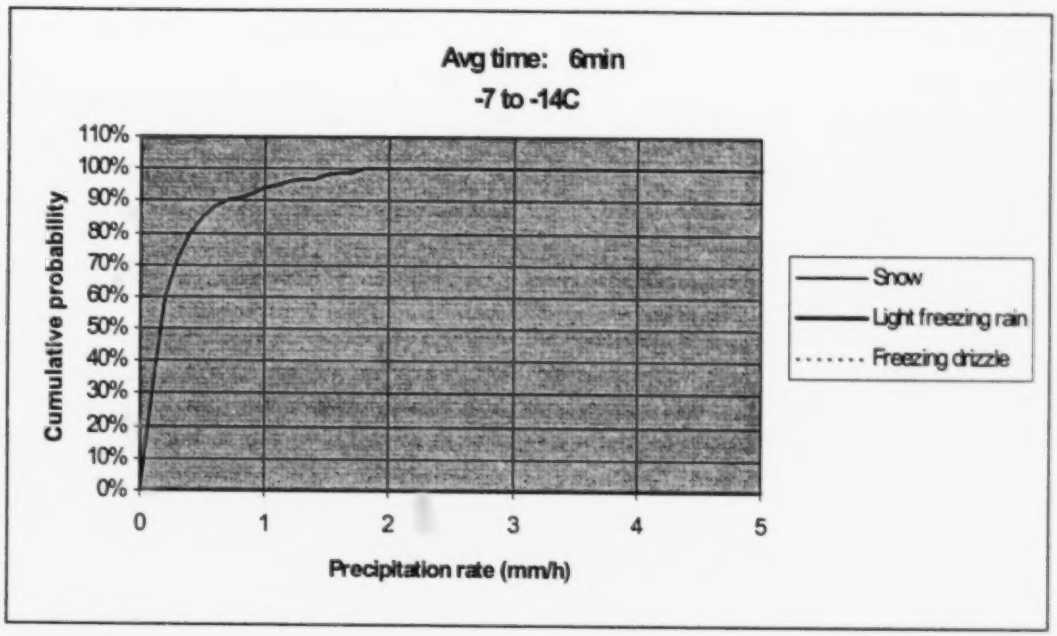
In light freezing rain the 95% percentile is also quite constant although other percentiles are more strongly affected.

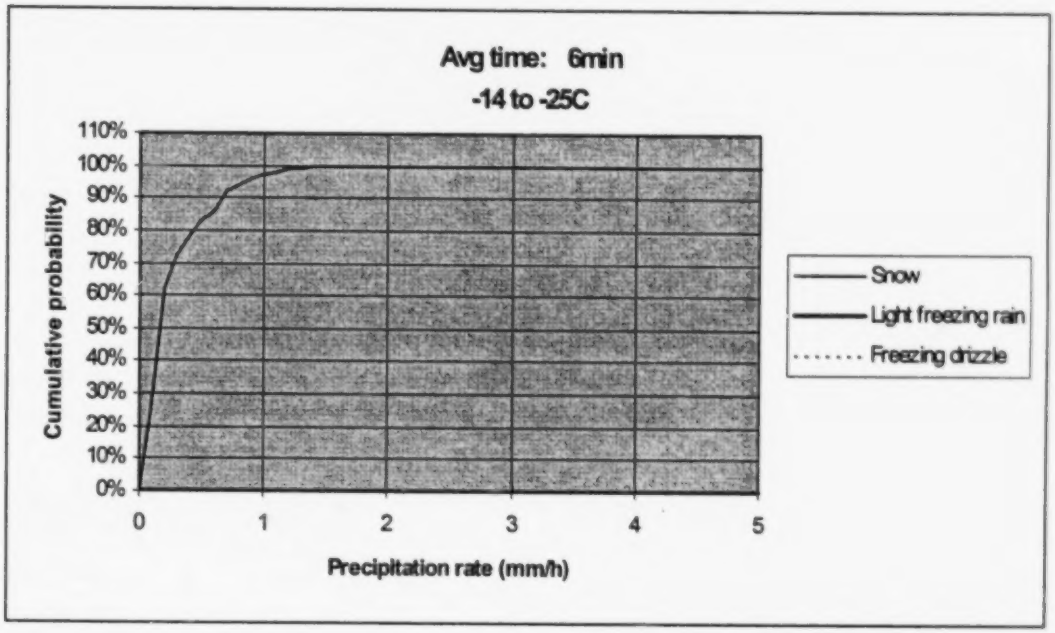
The averaging time will have the greatest influence when the precipitation rate is variable. This preliminary analysis indicates that the rates in snow are less variable than in light freezing rain.

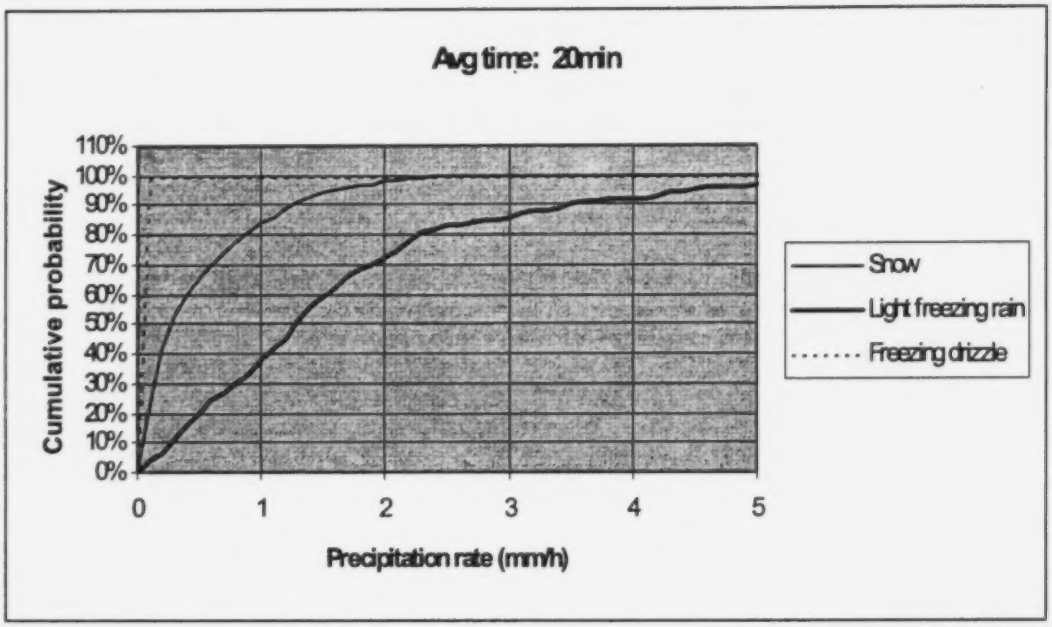
B.E. Sheppard
BRIAN.SHEPPARD@EC.GC.CA
17 Nov. 97

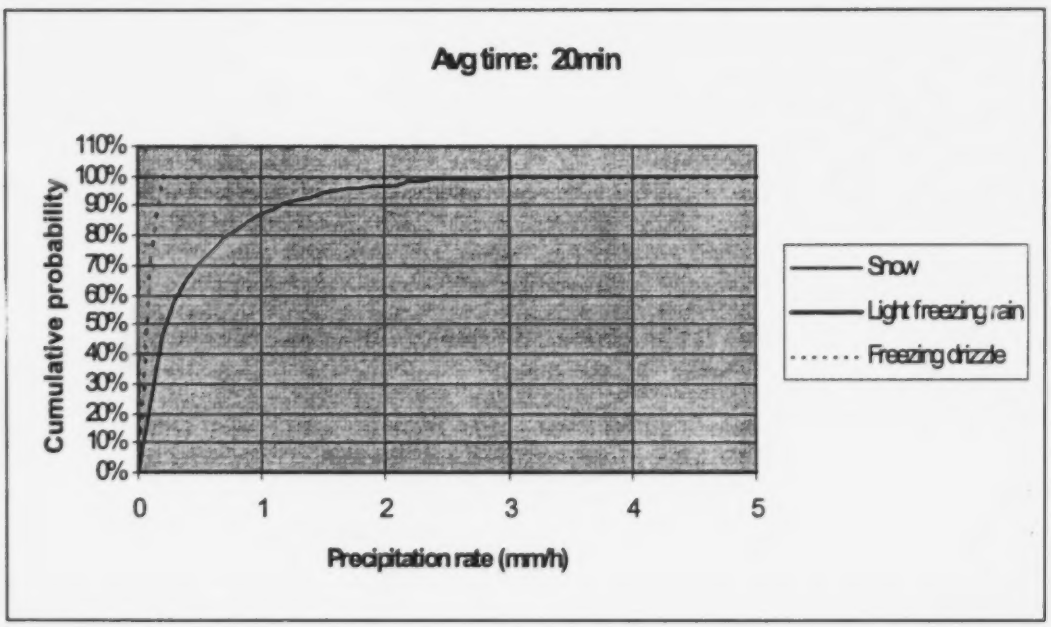

Avg time: 6min
0 to -3C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

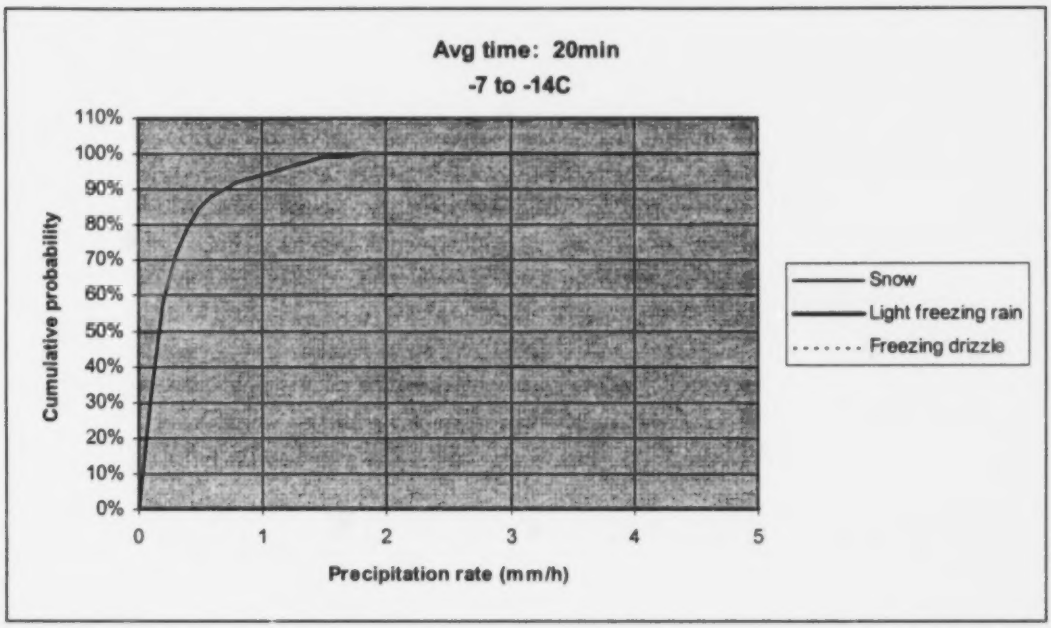

Avg time: 6min
-3 to -7C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

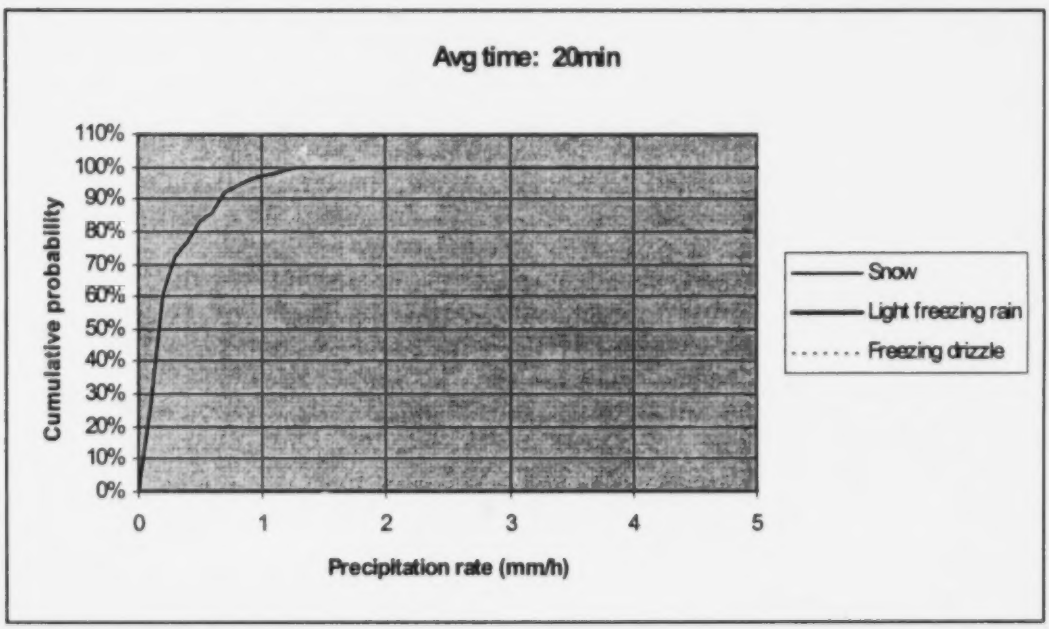

Avg time: 6min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

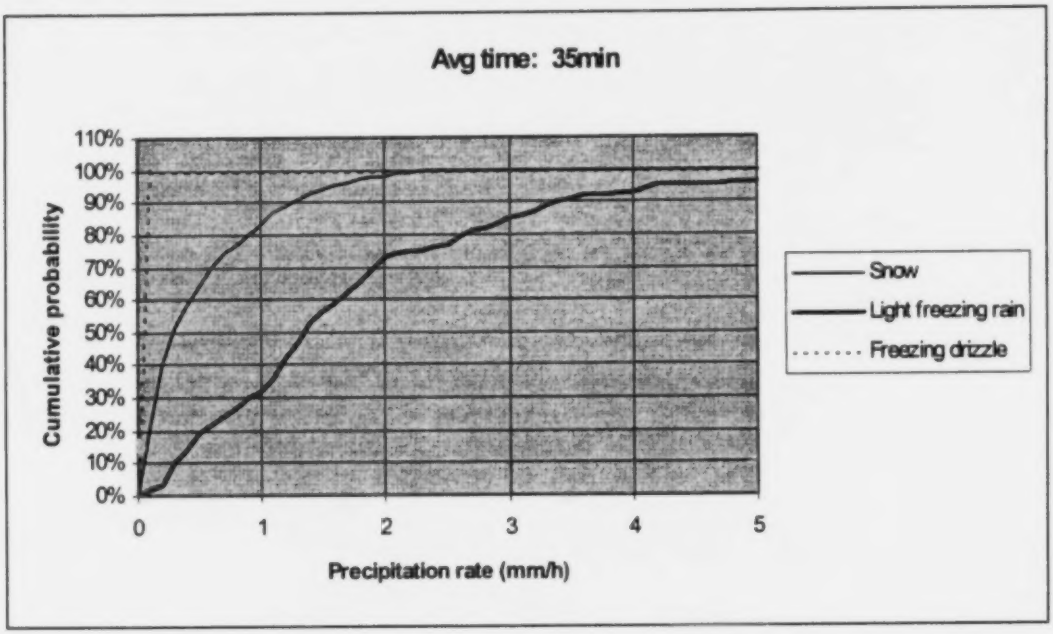

Avg time: 6min
-14 to -25C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

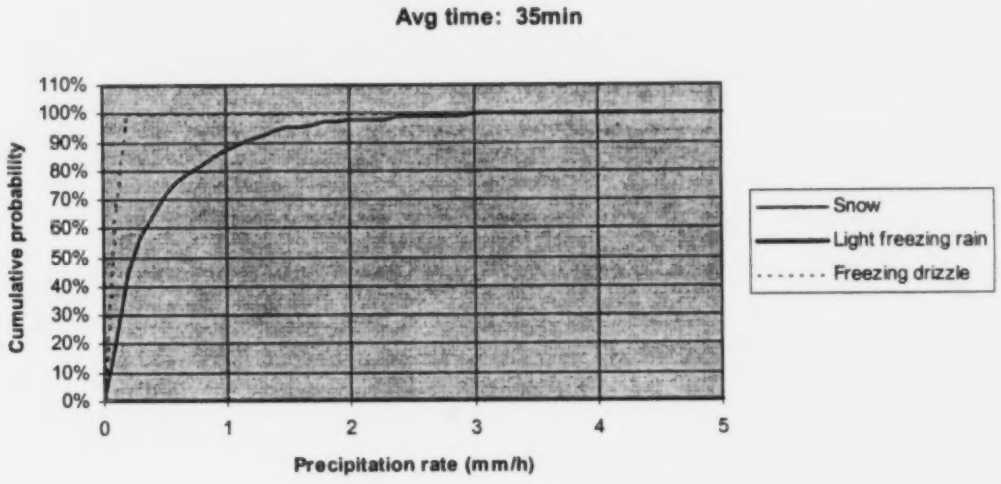

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

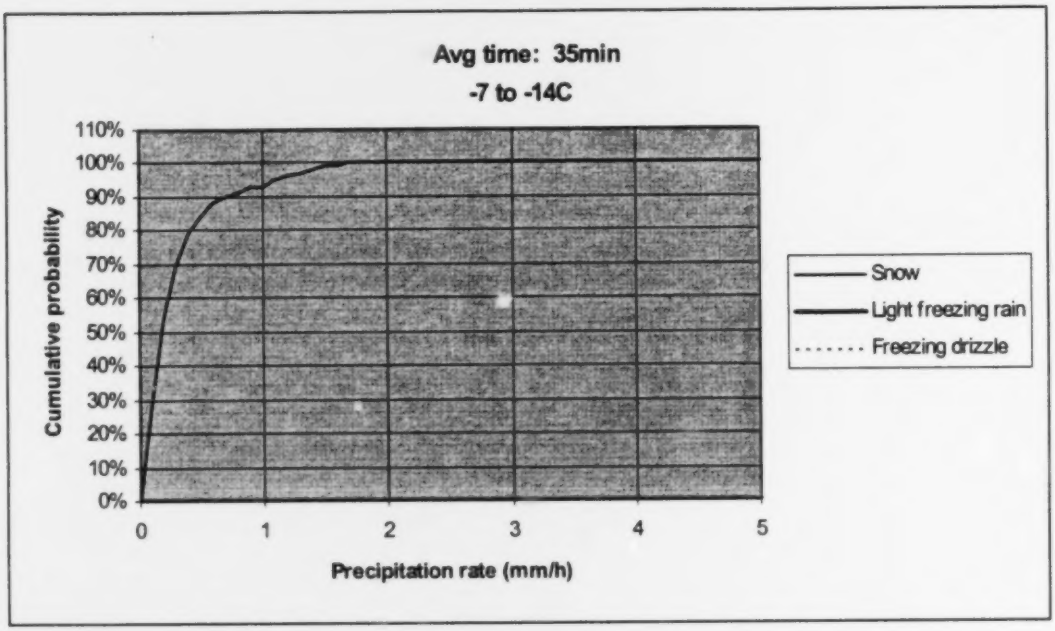

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

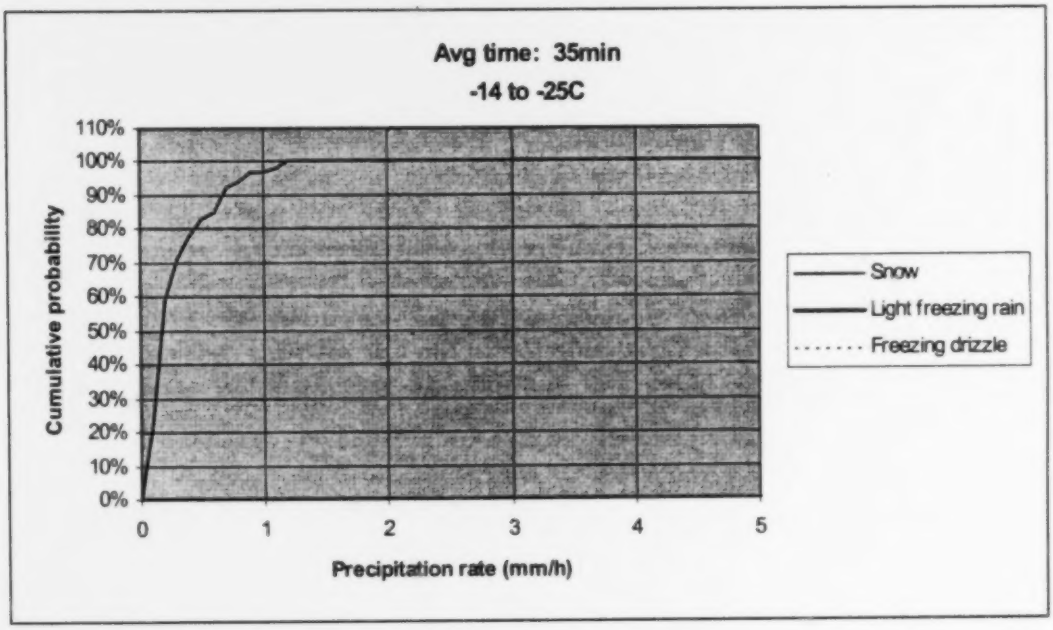

Avg time: 20min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

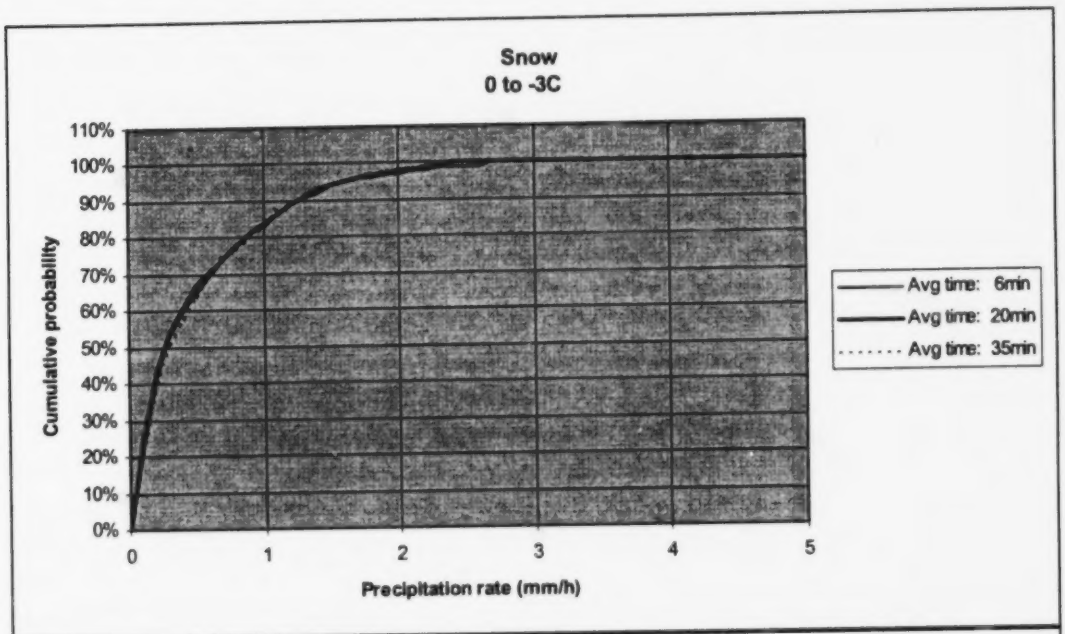

Avg time: 20min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle

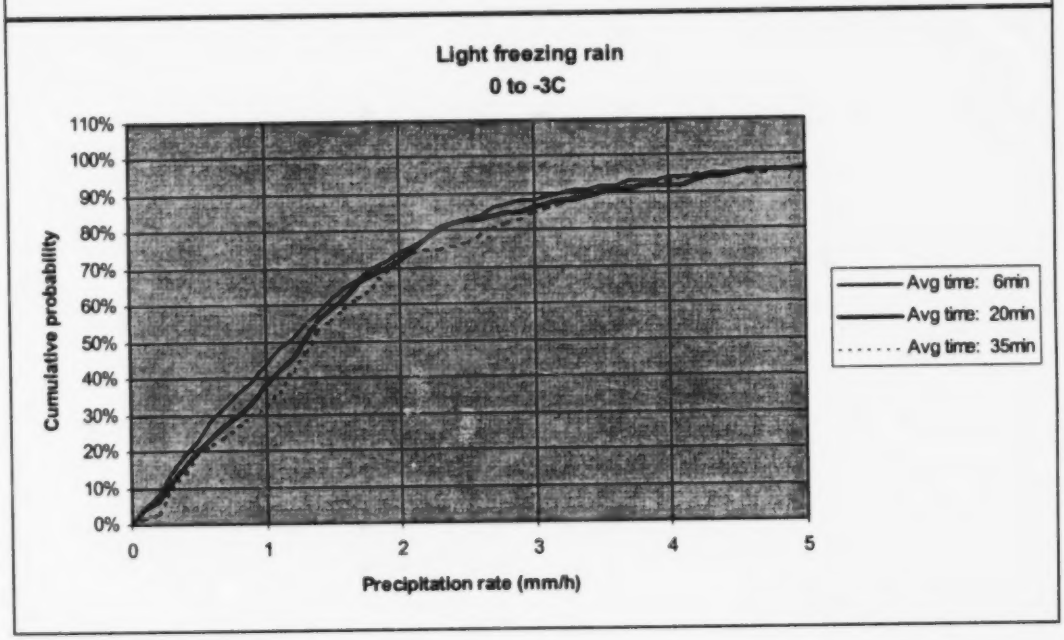

Avg time: 35min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-7 to -14C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Avg time: 35min
-14 to -25C
Cumulative probability
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
0
1
2
3
4
5
Precipitation rate (mm/h)
Snow
Light freezing rain
Freezing drizzle


Snow
0 to -3C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min


Light freezing rain
0 to -3C
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Cumulative probability
0
1
2
3
4
5
Precipitation rate (mm/h)
Avg time: 6min
Avg time: 20min
Avg time: 35min

APPENDIX E

MONTHLY METEOROLOGICAL SUMMARY
MONTREAL - DORVAL

Environnement Canada
Direction de l'environnement atmosphérique

Environment Canada
Atmospheric Environment Branch

SOMMAIRE MÉTÉOROLOGIQUE MENSUEL (c)
MONTHLY METEOROLOGICAL SUMMARY (c)

Avril 2000

Montreal - Dorval (AUTO)

April 2000

LAT 45' 28N LONG 73' 45W ALTITUDE 36 METRES (NMM) ELÉVATION 36 METRES (ASL) HEURE NORMALE UTILISÉE STANDARD TIME USED DE L'EST Eastern

DATE	TEMPÉRATURE TEMPERATURE			DEGRÉS-JOURS DEGREE-DAYS			HUMIDITÉ REL. REL. HUMIDITY		ORAGE THUNDERSTORM	PRÉCIPITATIONS PRECIPITATION			NEIGE AU SOL SNOW ON GROUND	VENTS WINDS				INSOLATION EFFECTIVE BRIGHT SUNSHINE
	MAXIMALE MAXIMUM °C	MINIMALE MINIMUM °C	MOYENNE MEAN °C	DE CHAUFFE HEATING Base 18 °C	DE CROISSANCE GROWING Base 5 °C	DE REFROIDISSEMENT COOLING Base 18 °C	MAXIMALE MAXIMUM %	MINIMALE MINIMUM %		PLUIE (HAUTEUR) RAINFALL mm	NEIGE (HAUTEUR) SNOWFALL cm	PRÉCIP TOTAL TOTAL PRECIP mm	cm	VITESSE MOYENNE AVERAGE SPEED km/h	DIRECTION DOMINANTE PREVAILING DIRECTN	VITESSE MOYENNE MAX SUR 2 MIN & DIRECTION km/h	MAX 2 MIN MEAN SPEED & DIRECTION	HEURES HOURS
1	13.3	0.7	7.0	11.0	2.0		88	38						15.0	W	SSW*	26	9.4
2	11.8	1.3	6.6	11.4	1.6		99	54		2.0		2.0		9.6	SW*	SW	20	
3	10.3	-1.6	4.4	13.6			100	64		1.0		1.0		12.5	NE*	E	22	2.1
4	9.6	4.1	6.9	11.1	1.9		100	87		15.0		15.0		19.3	WSW	WSW	46	
5	4.2	-1.0	1.6	16.4			99	64		1.1	0.4	1.5	TR	35.2	W	W	50	2.2
6	3.6	-0.8	1.4	16.6			99	59		0.5	1.6	2.0		11.1	E	WSW	22	0.8
7	8.6	0.9	4.8	13.2			96	66		0.5	TR	0.5		16.6	WSW	W*	28	6.5
8	5.6	-0.9	2.4	15.6			100	87		28.4	3.8	32.2		22.7	NE	NNE	37	
9	-0.9	-3.2	-2.1	20.1			100	93			33.9	35.5	12.0	27.2	W	W*	44	
10	5.2	-2.0	1.6	16.4			89	40			TR	TR	20.0	32.0	W	W	46	11.0
11	1.0	-3.2	-1.1	19.1			91	43			3.6	4.0	12.0	21.2	NE	NNE	31	1.0
12	4.0	-4.1	-0.1	18.1			91	34			1.4	1.4	16.0	20.7	W	W*	37	8.3
13	6.0	-4.8	0.6	17.4			71	37					10.0	14.8	SSW	WSW	31	11.4
14	13.5	-1.8	5.9	12.1	0.9		69	44					8.0	12.9	SSW	SSW*	22	8.7
15	21.9	3.2	12.6	5.4	7.6		78	56					2.0	20.3	SW*	WSW	37	8.1
16	10.4	0.4	5.4	12.6	0.4		75	36		TR		TR	TR	24.6	NNE	NNE	33	7.0
17	4.4	-2.1	1.2	16.8			55	34						22.7	NE	NE	33	1.5
18	11.4	-0.4	5.5	12.5	0.5		71	38						18.6	SSE	SSE	28	3.3
19	11.1	5.3	8.2	9.8	3.2		82	67						6.1	SSE	SE*	11	0.1
20	13.9	6.7	10.3	7.7	5.3		84	39						20.3	NE	NE	37	6.8
21	8.1	3.6	5.9	12.1	0.9		97	53		10.5		10.5		26.9	E	NE	43	
22	6.7	4.1	5.4	12.6	0.4		95	84		5.0		5.0		28.5	NE	NE	39	
23	7.7	4.0	5.9	12.1	0.9		96	77		0.5		0.5		21.7	NNE	NNE	33	
24	13.9	3.1	8.5	9.5	3.5		86	46		0.5		0.5		17.8	N	N*	31	4.4
25	10.1	1.5	5.8	12.2	0.8		63	33						24.2	NE	NE	35	13.4
26	10.7	1.1	5.9	12.1	0.9		68	37						21.3	NNE	NE	31	6.2
27	10.3	3.2	6.8	11.2	1.8		78	36		TR		TR		10.8	NNE	NNE	19	0.4
28	17.5	4.2	10.9	7.1	5.9		78	33						12.8	S	S	26	10.1
29	19.9	4.4	12.2	5.8	7.2		80	38	1	0.4		0.4		12.5	NW	N	37	10.7
30	13.5	2.5	8.0	10.0	3.0		63	23						16.4	WNW	WNW	31	13.6
	MOY 9.6 MEAN	MOY 0.9 MEAN	MOY 5.3 MEAN	TOTAL 381.6	TOTAL 48.7	TOTAL	MOY 84 MEAN	MOY 51 MEAN	TOTAL 1	TOTAL 65.4	TOTAL 44.7	TOTAL 112.0		MOY 19.2 MEAN	DOMINANTE PREVAILING NE	MAXIMALE W 50 MAXIMUM		TOTAL 147.0
NORMALE NORMAL	10.7	0.6	5.7	370.1	65.7	0.4			1	62.6	10.9	74.8		16.0	W			182.5

SOMMAIRE DE DEGRÉS-JOURS/DEGREE-DAY SUMMARY

AU-DESSOUS DE 18°C BELOW 18°C	ANNÉE EN COURS THIS YEAR	NORMALE NORMAL	AU-DESSUS DE 5°C ABOVE 5°C	ANNÉE EN COURS THIS YEAR	NORMALE NORMAL
TOTAL DU MOIS TOTAL FOR MONTH	381.6	370.1	TOTAL DU MOIS TOTAL FOR MONTH	48.7	65.7
ACCUMULÉS DEPUIS LE 1ER JUILLET ACCUMULATED SINCE JULY 1st	3925.5	4364.0	ACCUMULÉS DEPUIS LE 1ER AVRIL ACCUMULATED SINCE APRIL 1st	48.7	65.7

JOURS AVEC PRÉCIPITATIONS TOTALES DAYS WITH TOTAL PRECIPITATION

mm	0.5 OU PLUS OR MORE	1.0 OU PLUS OR MORE	2.0 OU PLUS OR MORE	10.0 OU PLUS OR MORE	50.0 OU PLUS OR MORE
	14	11	8	4	

JOURS AVEC CHÛTES DE NEIGE DAYS WITH SNOWFALL

cm	0.2 OU PLUS OR MORE	1.0 OU PLUS OR MORE	2.0 OU PLUS OR MORE	10.0 OU PLUS OR MORE	50.0 OU PLUS OR MORE
	6	5	3	1	

Canada

1. Normale/Normal 1961-1990
2. Journée climatologique/Climatological Day (01h00HNE à/to 01H00HNE)
3. (AUTO): mesures d'une station automatique/data from automatic station
4. TR=Trace M=Manquant/Missing E=Estimé/Estimated C=Calme/Calm
5. Pas de valeur/No entry=Pas d'événement/No occurrence
6. *=indique la première de plusieurs valeurs valides/indicates first of many valid values
7. c = correction

Données non contrôlées/Data is not validated
Les précipitations ont un seuil mesurable de 1,0 mm
Measurable threshold of precipitation is 1,0 mm

RELEVÉS COMPARATIFS À
COMPARATIVE RECORDS AT

Montreal - Dorval (AUTO)

Avril 2000
April 2000

		CE MOIS-CI THIS MONTH		ANNÉE PRÉCÉDENTE PREVIOUS YEAR		NORMALE NORMAL	RECORD POUR LE MOIS RECORD FOR THE MONTH						
							MAXIMUM ABSOLU HIGHEST EVER			MINIMUM ABSOLU LOWEST EVER			No. D'ANNÉES NO OF YEARS
		RELEVÉ VALUE	JOUR DAY	RELEVÉ VALUE	JOUR DAY		RELEVÉ VALUE	JOUR DAY	ANNÉE YEAR	RELEVÉ VALUE	JOUR DAY	ANNÉE YEAR	
TEMPÉRATURE MAXIMALE HIGHEST TEMPERATURE (MAXIMUM)	°CELSIUS	21.9	15	20.4	30		30.0	27	1990				59
TEMPÉRATURE MINIMALE LOWEST TEMPERATURE (MINIMUM)	°CELSIUS	-4.8	13	-3.5	5					-15.0	4	1954	59
TEMPÉRATURE MENSUELLE MOYENNE MEAN MONTHLY TEMPERATURE	°CELSIUS	5.3		6.9		5.7	9.4		1987	1.9		1943	59
HAUTEUR TOTALE MENSUELLE DE PLUIE TOTAL MONTHLY RAINFALL	Millimètres (mm) Millimetres (mm)	65.4		19.5		62.6	122.4	0	1991	17.4		1992	59
HAUTEUR TOTALE MENSUELLE DE NEIGE TOTAL MONTHLY SNOWFALL	Centimètres (cm) Centimetres (cm)	44.7 *				10.9	41.6	0	1993			1991	59
PRÉCIPITATION TOTALE MENSUELLE TOTAL MONTHLY PRECIPITATION	Millimètres (mm) Millimetres (mm)	112.0		19.5		74.8	177.8	0	1996	20.6		1966	59
NOMBRE DE JOURS AVEC PRÉCIPITATION MESURABLE NO OF DAYS WITH MEASURABLE PRECIPITATION		15		7		13	21	0	1996	7		1975	59
HAUTEUR DE PLUIE MAXIMALE EN UNE JOURNÉE GREATEST RAINFALL IN ONE DAY	Millimètres (mm) Millimetres (mm)	28.4	8	7.0	8		40.4	21	1991				59
HAUTEUR DE NEIGE MAXIMALE EN UNE JOURNÉE GREATEST SNOWFALL IN ONE DAY	Centimètres (cm) Centimetres (cm)	33.9	9		1		31.2	1	1993				59
PRÉCIPITATION MAXIMALE EN UNE JOURNÉE GREATEST PRECIPITATION IN ONE DAY	Millimètres (mm) Millimetres (mm)	35.5	9	7.0	8		40.4	21	1991				59
HAUTEUR DE PLUIE ENREGISTRÉE EN MAXIMUM RAINFALL RECORDED IN													
5 MINUTES	Millimètres (mm) Millimetres (mm)						3.2	1	1981				46
10 MINUTES	Millimètres (mm) Millimetres (mm)						4.8	4	1963				46
15 MINUTES	Millimètres (mm) Millimetres (mm)						6.6	4	1963				46
30 MINUTES	Millimètres (mm) Millimetres (mm)						8.4	4	1963				46
60 MINUTES	Millimètres (mm) Millimetres (mm)						10.2	4	1963				46
24 HEURES CONSÉCUTIVES CONSECUTIVE HOURS	Millimètres (mm) Millimetres (mm)												
VITESSE MOYENNE DU VENTS (KM/H) MEAN WIND SPEED (KM/H)		19.2		17.2		16.0	22.1		1973	11.7		1971	59
VITESSE MAXIMALE (MOYENNE SUR 2 MIN.) (KM/H) MAXIMUM SPEED (2 MIN. MEAN) (KM/H)		W 50	5	W 48	7		W 70	3	1977				59
POINTE DU VENT MAXIMALE (KM/H) MAXIMUM GUST SPEED (KM/H)		W 67	5	WSW 80	7		WSW 106	19	1975				59
TOTAL DES HEURES INSOLATION TOTAL HOURS OF SUNSHINE		147.0		245.0		182.5	245.0		1999	102.3		1983	29
PRESSION MOYENNE À LA STATION (kPa) MEAN STATION PRESSURE (kPa)		100.99		100.99		100.98	101.56		1954	100.42		1953	59
PRESSION MAXIMALE À LA STATION (kPa) GREATEST STATION PRESSURE (kPa)		102.87	13	102.48	5		103.50	28	1966				59
PRESSION MINIMALE À LA STATION (kPa) LEAST STATION PRESSURE (kPa)		98.75	4	99.43	16					97.22	2	1970	59

DONNÉES CLIMATOLOGIQUES CE MOIS-CI POUR LES 10 DERNIÈRES ANNÉES
CLIMATOLOGICAL DATA THIS MONTH FOR THE PAST 10 YEARS

ANNÉE YEAR	TEMP MAXIMALE MAXIMUM TEMP	TEMP MINIMALE MINIMUM TEMP	TEMP MOYENNE MEAN TEMP	HAUTEUR DE PLUIE RAINFALL	HAUTEUR DE NEIGE SNOWFALL	PRÉCIP TOTALE TOTAL PRECIP	VITESSE MOYENNE DES VENTS MEAN WIND SPEED	VITESSE MAXIMALE DES VENTS MEAN WIND SPEED	HEURES INSOLATION SUNSHINE HOURS	DEGRÉS-JOURS DE CHAUFFE HEATING DEGREE-DAYS	DEGRÉS-JOURS DE CROISSANCE GROWING DEGREE-DAYS	DEGRÉS-JOURS DE RÉFRIGÉRATION COOLING DEGREE-DAYS	A S N S A S
1991	21.5	-4.4	7.8	122.4	TR	122.4	13.9	NE 63	162.8	305.0	98.4		197.0
1992	24.3	-8.3	4.9	17.4	23.8	41.2	13.9	W 37	193.1	392.4	58.1		206.5
1993	22.2	-6.4	5.9	110.6	41.6	24.2	12.7	NE 54	114.3	364.2	64.6		242.0
1994	22.2	-8.4	5.3	74.4	24.2	98.6	15.7	WSW 48	156.9	380.2	53.0		274.4
1995	16.4	-14.5	3.7	69.2	1.0	70.2	15.7	W 50	187.2	427.6	44.6		186.7
1996	20.2	-7.7	5.0	151.9	24.3	184.4	15.2	WSW 59	135.0	388.8	46.4		213.6
1997	21.7	-10.9	4.8	60.9	26.6	96.9	14.8	SW 50	226.5	397.2	54.0		305.4
1998	22.3	-2.1	8.1	35.0	TR	35.0	14.5	WSW 44	238.9	298.3	103.6		246.4
1999	20.4	-3.5	6.9	19.5	0.0	19.5	17.2	W 48	245.0	332.3	70.8		161.3
2000	21.9	-4.8	5.3	65.4	44.7	112.0	19.2	W 50	147.0	381.6	48.7		223.4

Note: * Nouveau record / New record

A.S.N.= Accumulation saisonnière de neige / S.A.S.= Season accumulation snowfall

Température horaire Hourly temperature	Montreal - Dorval (AUTO)																				Avril 2000 April 2000			
DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	39	33	26	28	29	16	9	24	44	53	77	92	101	116	123	131	129	128	114	114	97	89	72	78
2	77	69	69	62	65	57	59	75	83	91	97	95	105	108	116	107	98	96	89	79	59	47	36	34
3	25	22	11	10	-2	-1	9	41	65	67	74	76	85	93	100	96	91	88	84	81	84	86	84	85
4	86	76	79	74	73	76	76	86	87	84	79	68	72	79	83	82	87	93	91	86	74	72	68	58
5	49	41	38	33	16	7	7	2	4	4	-4	-2	-5	-10	-6	-2	-1	2	2	6	9	9	7	12
6	7	6	-1	-1	0	-1	9	13	21	27	35	33	14	15	14	15	18	21	15	14	15	15	13	14
7	16	17	15	14	15	13	9	17	26	42	49	57	65	71	79	77	80	73	69	63	63	47	53	62
8	55	55	48	45	45	42	42	41	40	40	42	39	25	27	25	24	22	24	20	13	6	2	1	1
9	-6	-9	-13	-17	-21	-26	-26	-30	-30	-31	-32	-30	-29	-28	-30	-28	-23	-20	-20	-20	-21	-20	-21	-20
10	-20	-19	-20	-9	-2	2	-3	-4	-3	5	11	19	28	36	39	45	47	51	44	33	33	26	20	14
11	11	8	3	1	-5	-15	-26	-29	-29	-24	-17	-14	-11	-8	-9	-7	-12	-20	-24	-25	-26	-25	-26	-27
12	-28	-32	-31	-32	-31	-30	-31	-29	-24	-16	-17	3	17	24	28	37	37	31	27	15	-2	-14	-13	-28
13	-31	-41	-44	-45	-44	-47	-36	-16	3	3	23	36	46	52	54	55	57	57	55	47	42	31	30	22
14	17	11	3	-2	-1	-13	2	5	23	40	48	68	79	91	107	120	130	125	122	111	93	87	97	90
15	74	72	73	51	60	62	56	75	93	109	126	158	186	197	209	216	215	210	202	192	102	86	76	68
16	62	60	56	54	52	48	46	45	44	46	51	67	80	89	99	100	100	96	85	65	47	34	24	15
17	11	8	2	-4	-11	-15	-19	-18	-14	-6	0	9	17	29	27	36	39	41	42	37	38	35	37	40
18	30	11	18	14	10	-1	4	15	31	52	66	78	87	100	107	109	111	104	93	82	73	67	66	65
19	61	58	58	57	55	55	55	58	62	67	77	84	97	100	103	106	108	107	104	102	96	97	94	89
20	88	85	79	71	75	69	69	72	83	87	101	102	118	126	129	134	134	126	122	118	115	107	97	89
21	79	69	65	59	53	44	38	37	40	45	48	57	74	77	79	75	72	68	63	62	60	57	54	51
22	48	47	49	44	43	42	42	44	47	48	50	55	58	62	66	65	63	58	57	48	46	46	46	45
23	44	44	44	41	41	41	41	44	47	47	51	52	55	61	67	75	74	72	68	59	58	64	68	70
24	68	69	71	68	68	61	58	71	77	84	93	110	112	125	129	130	132	125	101	80	63	71	42	44
25	48	35	22	21	21	16	22	31	48	55	67	65	80	89	90	93	96	96	93	85	74	66	54	45
26	37	24	20	17	15	18	29	41	57	67	68	85	88	104	101	101	101	100	97	96	92	93	95	84
27	69	61	51	43	39	33	35	39	42	55	65	69	76	86	100	97	90	76	71	65	62	57	57	57
28	51	48	48	46	48	47	53	55	60	75	87	104	122	141	156	167	172	174	169	142	115	117	101	97
29	111	97	75	76	65	64	72	102	133	134	153	163	167	185	183	195	156	132	114	100	94	84	63	62
30	55	46	39	38	36	27	45	61	66	80	96	109	114	115	122	133	130	127	119	105	78	87	69	71

Unités / Units: 0.1 °C M = Manquant /Missing

Lire / Read -123 = -12.3 °C -1 = -0.1 °C 0 = 0.0 °C 12 = +1.2 °C 123 = +12.3 °C

Heure normale locale: Est Local standard time: Eastern

Si vous avez des questions, commentaires ou désirez recevoir de l'information sur les produits offerts par Environnement Canada:
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100, ALEXIS NIHON, 3e
VILLE ST-LAURENT, QC - H4M 2N8 TÉLÉCOPIEUR / FAX (514) 283-2264
Courrier éléctronique/Email: **Climat.Quebec@ec.gc.ca**
Renseignements climatologiques / Climate Informations :1-900-565-1111

Vents horaires (km/h)
Hourly winds (km/h)

Montreal - Dorval (AUTO)

Avril 2000
April 2000

Heure normale locale: Est
Local standard time : Eastern

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	Rafale max Peak Gust	heure time	jour day
1	SW	WSW	W	SW	WSW	WSW	W	WSW	W	W	W	W	SW	WSW	SSW	SW	WSW	WSW	W	SW	W	SW	S	SSE	SSW		
	19	20	11	9	9	13	11	15	20	11	17	17	20	22	26	24	26	22	17	15	15	7	6	6	39	14	1
2	S	S	S	SSE	SSE	S	SW	C	SSE	SSE	SSW	S	SSW	SSW	SSW	SSW	SW	SW	W	W	WNW	WNW	WNW	SW			
	9	11	4	6	6	9	4	0	11	4	6	11	19	15	11	17	20	19	17	11	11	13	6	7			
3	SW	C	S	C	NE	NE	NNE	NE	SE	ENE	NE	NE	NE	E	E	E	ESE	E	E	E	ENE	ENE	ENE	ENE			
	4	0	6	0	4	6	6	7	13	13	15	15	13	9	15	22	15	17	15	15	19	17	17	17			
4	E	NE	ENE	NE	NE	NE	N	ENE	ENE	NE	NW	NNW	W	WSW	WSW	WSW	SW	WSW	WSW	SW	W	WSW	WSW	SW	WSW		
	13	11	13	13	19	19	11	17	9	9	15	13	7	17	17	17	20	22	19	17	26	26	26	35	54	1	5
5	WSW	WSW	WSW	WSW	WSW	WSW	W	W	W	W	W	W	W	WSW	W	W	W	W	W	W	W	W	W	W	W		
	31	46	41	35	35	28	35	30	41	35	39	39	44	46	50	37	43	35	33	31	37	33	28	33	67	12	5
6	W	W	W	W	WSW	SW	SW	SW	S	S	SSE	SE	E	ENE	E	E	E	ENE	NNE	N	N	N	NNW	WNW			
	17	19	17	17	22	7	7	11	9	7	7	13	11	13	17	13	9	11	7	7	6	9	9	9			
7	WSW	WSW	WSW	WSW	WSW	WSW	WSW	SW	WSW	SW	WSW	W	W	W	W	W	W	WSW	SW	SSW	WSW	NW	NE	E	W		
	13	15	17	20	15	15	13	17	26	20	19	26	28	28	19	22	22	17	9	9	6	9	6	9	41	12	7
8	SE	E	NE	NE	NE	NE	ENE	NE	NE	NE	NE	N	NNE	NNE	NNE	NNE	N	N	N	NNW	NW	NW	NW	WNW	N		
	11	15	22	22	20	24	28	30	26	26	22	22	33	31	30	37	33	22	30	13	6	7	13	15	50	16	8
9	NNW	N	N	NNW	NNW	NW	WNW	NW	NW	WNW	NW	NW	WNW	W	W	W	W	W	W	W	W	W	W	W	W		
	20	13	17	15	19	15	15	13	17	17	17	19	17	20	33	28	28	30	35	44	43	39	41	44	65	0	9
10	W	W	W	WNW	W	W	W	W	W	W	WSW	W	W	W	W	W	W	W	W	W	SW	SW	WSW	WSW	W		
	43	43	46	43	39	37	33	43	41	35	41	44	41	41	39	39	39	24	17	9	15	31	26	20	67	2	10
11	WSW	NW	WNW	NNW	N	NNE	NNE	NE	ENE	NE	NE	NE	NE	NE	NE	ENE	ENE	NE	NE	NNE	NE	NE	NE	NNE	NNE		
	15	11	7	13	17	24	24	22	28	24	20	19	19	15	15	17	17	20	19	28	24	22	28	30	44	0	11
12	NNE	NNE	N	N	N	NNW	NNW	WNW	W	W	W	W	W	WNW	W	W	WNW	NW	NW	NW	NW	NW	WNW	WNW	WNW		
	26	31	24	26	28	20	15	19	22	26	19	22	33	26	37	37	30	17	20	11	11	11	13	11	46	13	12
13	WNW	W	WNW	WNW	WNW	W	SSW	WSW	SW	SSW	SSW	SSW	SW	WSW	WSW	W	WSW	WSW	WSW	SW	SW	SSW	SSW	SSW	W		
	11	7	9	9	7	4	6	4	4	11	17	13	22	31	26	24	30	24	22	15	13	15	13	15	41	15	13
14	S	SW	S	SSE	SSE	SSE	ESE	SSE	SE	SSE	SSE	S	SSE	SSW	SSW	SSW	SW	SSW	SSW	SSW	S	SSW	SSW	SSW			
	13	7	6	11	7	6	9	13	7	11	13	11	13	15	15	22	20	22	15	13	13	19	19				
15	S	SE	ESE	ENE	SSE	ESE	SSE	SE	ESE	SSE	SSW	SW	SW	SW	SW	SW	WSW	WSW	WSW	WSW	NE	NE	NE	NE	W		
	11	6	7	6	6	9	6	9	6	6	6	19	31	31	28	30	37	35	24	22	31	30	30	30	59	16	15
16	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NE	N	N	NNW	N	N	NNE	NNE	NNE	NNE	NNE	NNE	NNE	NNE		
	30	19	31	28	22	28	26	17	31	24	30	22	20	20	15	13	13	26	28	26	33	31	30	26	41	20	16
17	NNE	NNE	NNE	NE	NE	NNE	NE	NE	ENE	NE	ENE	ENE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	ENE	NNE		
	24	26	22	24	33	28	31	31	31	28	26	20	22	22	19	17	22	22	17	17	17	20	19	20	46	6	17
18	NE	NNE	NNE	NNE	NNE	NNE	NNE	NE	NE	NE	NE	ENE	ENE	E	ESE	E	SSE	SSE	SSE	S	SSE	SSE	SSE	SSE	SSE		
	17	20	15	15	19		20	26	20	20	20	17	13	13	11	9	13	13	19	19	20	26	26	28	39	22	18
19	SSE	SSE	SSE	S	SSE	SE	SE	SSE	SE	S	S	S	SE	SSE	SSE	W	SSW	C	C	SW	WNW	C	SSE	W			
	26	17	9	7	7	7	11	7	9	7	6	7	6	4	6	9	4	0	0	6	4	0	6	4			
20	NE	N	NNE	NNE	NNE	NNE	NNE	ENE	N	NE	NNE	ENE	ENE	ENE	NNE	NE	ENE	NE	E	ENE	ENE	NE	NE	NE	ENE		
	11	9	17	22	19	19	20	19	13	17	13	19	9	13	19	9	9	19	20	17	28	33	31	37	48	23	20
21	NE	NE	NNE	NE	NE	NE	NE	NE	NE	NE	NE	NE	E	E	E	E	E	E	E	E	E	E	E	E	NE		
	31	35	37	33	28	30	43	33	31	24	28	31	24	28	28	20	26	17	24	20	20	30	24	26	56	6	21
22	E	ENE	ENE	ENE	ENE	NE	NE	NE	NE	ENE	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	NE	NE	NE	NE		
	26	15	19	20	17	19	20	24	30	30	30	30	30	30	35	39	33	30	30	33	31	26	31	35	50	15	22
23	NE	NE	NE	NE	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	NNE	NNE	N	NNE	NE	NE	NNE	N	N	NNE	NNE	NNE	NE		
	35	26	28	24	31	28	26	24	24	28	22	33	30	30	17	13	13	13	15	17	9	19	26	22	50	11	23
24	N	NNW	NNW	N	NNE	N	N	NNW	NNW	NNW	NNW	N	NNE	N	ENE	ENE	ENE	E	ESE	SSE	SSE	SE	C	N	N		
	13	15	13	11	20	31	20	28	24	28	24	26	22	31	15	17	17	17	17	15	7	6	0	7	46	13	24
25	NNE	N	N	NNE	NNE	N	NNE	NE	ENE	NE	NNE	NNE	NE	NE	NE	NE	ENE	ENE	ENE	E	E	NE	NE	NNE	ENE		
	19	13	13	15	17	22	24	31	24	24	24	22	26	31	35	28	31	26	22	22	15	22	26	31	50	16	25
26	NE	NNE	NNE	NNE	NNE	NNE	NNE	ENE	NE	ENE	NE	NE	ENE	NE	NE	NE	NNE	NNE	NNE	NNE	NNE	NNE	ENE	NNE	NE		
	28	22	22	20	22	19	20	30	31	24	26	19	24	24	26	26	24	22	24	19	11	11	19	15	48	13	26
27	N	NNE	NNE	NNE	NNE	N	N	NNE	NNE	N	NNE	NNE	NNW	NE	E	NE	ENE	E	NNE	E	N	NNE	N	NE	NNW		
	13	19	15	19	17	15	13	15	13	7	7	6	7	6	7	17	11	11	13	4	11	11	7	9	35	16	27
28	N	NNE	NNE	C	SW	C	C	SW	SW	SSW	SW	SSW	S	SSW	S	S	S	S	SSW	SE	SSE	SE	SSE	S			
	6	11	9	0	4	0	0	11	13	13	19	17	17	15	26	22	19	15	17	20	19	15	7	9			
29	SSW	SW	SSW	SW	W	WSW	C	ENE	ENE	SSE	SSE	S	ESE	NNW	W	WNW	N	NNE	NNE	NE	N	NNW	NW	WNW	NNE		
	13	7	11	6	7	6	0	4	11	7	11	9	4	13	15	4	37	28	26	20	22	11	7	11	50	17	29
30	NW	NW	NNW	NNW	NNW	NNW	NNW	N	N	WNW	NNW	WNW	WNW	WNW	NW	NW	WNW	NNW	WNW	WNW	NW	NW	WNW	NW	WNW		
	15	15	11	15	15	13	17	22	15	19	17	31	24	20	22	19	28	28	15	15	11	7	9	7	57	11	30

Avis/Note

C= Calme /Calm

M= Manquant /Missing

Points de rosée horaires — Montreal - Dorval (AUTO) — Avril 2000
Hourly dew points — April 2000

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	6	4	3	2	-1	-5	-9	-5	2	-2	8	16	18	15	15	7	-11	-5	0	-4	-2	-11	2	2
2	-7	-6	-17	-8	-6	3	-2	-4	5	8	13	63	71	79	87	84	90	89	79	71	57	38	29	29
3	24	21	11	10	-2	-1	9	29	42	38	40	44	39	30	38	32	55	54	54	52	53	55	56	61
4	65	69	76	74	73	76	76	80	80	82	79	68	72	76	76	75	78	86	83	75	56	56	52	40
5	37	22	14	12	9	5	1	-15	-19	-18	-31	-50	-57	-57	-55	-58	-55	-55	-47	-44	-49	-51	-50	-49
6	-43	-43	-33	-30	-32	-35	-29	-25	-25	-27	-37	-15	3	10	4	6	12	12	12	11	12	12	12	12
7	13	12	9	9	8	5	0	3	10	21	13	21	21	20	20	19	24	18	13	22	22	27	25	24
8	29	27	28	32	35	34	35	35	33	34	39	36	23	23	21	20	16	17	14	9	4	2	1	0
9	-11	-11	-17	-21	-27	-32	-30	-36	-35	-36	-35	-35	-35	-28	-31	-28	-23	-20	-20	-20	-26	-30	-27	-24
10	-28	-28	-40	-53	-64	-71	-70	-68	-77	-84	-84	-80	-70	-69	-74	-75	-70	-75	-72	-65	-65	-9	-4	-4
11	-5	-34	-30	-46	-58	-63	-86	-131	-136	-119	-112	-110	-109	-105	-98	-89	-73	-54	-42	-38	-38	-38	-42	-40
12	-41	-44	-44	-45	-51	-51	-53	-48	-52	-50	-51	-68	-87	-107	-100	-96	-106	-112	-107	-103	-96	-96	-105	-106
13	-111	-106	-107	-110	-108	-101	-97	-73	-87	-71	-81	-75	-88	-78	-64	-69	-64	-65	-67	-45	-29	-29	-40	-31
14	-46	-36	-49	-56	-60	-64	-62	-53	-47	-37	-34	-36	-16	-24	-9	11	22	27	30	29	32	23	25	22
15	20	19	17	15	22	16	20	30	42	51	62	86	107	115	122	129	124	121	119	120	57	45	38	27
16	23	21	13	10	11	4	-7	3	-2	-6	-4	4	11	3	2	-21	-34	-46	-55	-70	-73	-80	-72	-71
17	-73	-77	-95	-107	-115	-107	-131	-123	-134	-124	-125	-111	-119	-99	-109	-93	-96	-100	-91	-87	-87	-93	-98	-104
18	-97	-69	-80	-78	-61	-48	-44	-65	-61	-49	-42	-31	-24	-30	-23	-27	-28	-24	-12	-4	1	1	3	0
19	0	6	6	10	9	12	15	16	19	23	22	27	43	45	47	51	51	50	54	51	55	52	61	60
20	54	56	51	45	42	42	41	37	40	40	41	39	45	37	22	20	13	13	12	8	-8	-17	-33	-42
21	-31	-26	-24	-20	4	10	15	21	30	38	44	52	67	66	64	52	53	51	44	41	41	38	35	30
22	28	28	25	30	34	33	35	33	34	32	36	36	42	49	48	44	49	47	45	40	39	35	31	32
23	29	29	27	24	23	23	23	27	28	29	29	29	34	45	52	60	60	60	59	53	49	48	45	44
24	42	31	21	18	22	19	20	20	16	7	8	16	14	17	22	25	19	25	32	32	29	29	21	22
25	-1	-30	-46	-59	-70	-72	-74	-67	-50	-49	-35	-36	-42	-43	-52	-62	-60	-60	-63	-61	-50	-67	-60	-71
26	-59	-39	-39	-37	-38	-38	-36	-33	-21	-20	-20	-11	-21	-17	-32	-38	-38	-32	-38	-38	-34	-35	-41	-35
27	-20	-29	-30	-33	-35	-39	-41	-35	-29	-18	-13	-17	-18	-42	-37	-47	-32	-19	-3	18	13	14	9	13
28	12	13	12	8	9	10	12	20	18	23	23	31	30	39	25	5	6	10	9	50	46	36	34	36
29	38	42	43	40	29	29	40	48	30	59	57	56	46	54	41	50	85	51	42	37	41	-3	8	-1
30	0	-9	-24	-37	-46	-48	-44	-42	-56	-39	-56	-61	-56	-60	-55	-55	-66	-74	-83	-72	-65	-74	-66	-71

Unités / Units: 0.1 °C — M = Manquant / Missing

Humidités relatives horaires — Avril 2000
Hourly relative humidities — April 2000

DATE	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	79	81	85	83	81	86	88	81	74	68	62	59	56	50	48	43	38	40	45	44	50	49	61	59
2	55	59	54	61	60	68	65	57	58	56	56	80	79	82	82	86	95	95	93	95	99	94	95	97
3	99	99	100	100	100	100	100	92	85	82	79	80	73	65	65	64	78	79	81	82	81	81	83	85
4	87	95	98	100	100	100	100	96	95	99	100	100	100	98	95	95	94	95	95	93	88	90	90	88
5	92	87	84	86	95	99	96	88	84	85	82	70	68	70	69	66	67	65	70	69	65	64	66	64
6	69	70	79	81	79	78	76	76	72	68	59	71	92	96	93	94	96	94	98	98	98	98	99	99
7	98	96	96	96	95	94	94	90	89	86	77	78	73	70	66	67	68	68	67	75	75	87	82	77
8	83	82	87	91	93	95	95	96	95	96	98	98	99	97	97	97	96	95	96	97	99	100	100	99
9	96	99	97	97	96	96	97	96	96	96	98	96	96	100	99	100	100	100	100	100	96	93	96	97
10	94	94	86	72	63	58	60	62	57	51	49	48	48	46	43	41	42	40	43	49	49	78	84	88
11	89	73	78	71	67	70	63	45	43	48	48	48	47	48	51	54	63	77	87	91	91	91	89	91
12	91	91	91	91	86	85	85	87	81	78	78	59	46	37	38	37	34	34	36	41	49	53	49	55
13	54	60	61	60	61	66	63	65	51	57	46	44	37	38	42	40	41	41	41	51	60	65	60	68
14	63	71	68	67	64	68	62	65	60	57	55	47	51	44	44	47	48	51	53	57	66	64	61	62
15	69	69	68	78	77	72	78	73	70	67	65	62	60	59	57	58	56	57	59	63	74	75	77	75
16	76	76	74	73	75	73	68	74	72	69	68	64	62	55	51	43	39	36	37	37	41	43	49	53
17	53	53	48	46	45	49	42	44	39	40	38	40	36	38	36	38	37	35	37	40	39	38	36	34
18	39	55	48	50	59	71	70	55	51	48	46	46	46	40	40	38	38	41	48	55	60	63	64	63
19	65	69	69	72	72	74	75	74	74	73	68	67	69	69	68	69	68	68	71	71	76	74	80	82
20	79	82	82	84	80	83	82	78	74	72	66	65	61	55	48	46	44	46	47	47	42	42	40	39
21	46	51	53	57	71	79	85	89	93	95	97	97	95	93	90	85	88	89	88	86	88	88	88	86
22	87	87	84	91	94	94	95	93	91	89	91	88	89	91	88	86	91	93	92	95	95	93	90	91
23	90	90	89	89	88	88	88	89	87	88	86	85	86	89	90	90	91	92	94	96	94	89	85	83
24	83	77	70	70	72	74	77	70	65	58	55	52	51	48	48	49	46	50	62	72	79	75	86	86
25	70	62	61	55	51	52	49	48	49	47	48	48	42	39	36	33	33	33	33	35	41	38	44	43
26	49	63	65	67	68	66	62	58	57	54	53	51	46	43	39	37	37	39	38	39	41	40	38	43
27	53	52	56	58	58	59	57	58	60	59	57	54	51	40	38	36	42	51	59	72	71	74	71	73
28	76	78	77	76	76	77	75	78	74	70	64	61	53	50	41	33	33	33	34	54	63	58	63	66
29	61	69	80	78	78	78	80	69	50	60	53	49	45	42	39	38	63	58	61	65	69	54	68	64
30	68	67	63	58	55	58	52	48	41	43	34	30	30	29	29	27	25	24	23	28	35	31	37	36

Unités / Units: pourcent / percent (%) — M = Manquant / Missing

Sommaire quotidien de avril 2000
Aéroport International de Montréal/Dorval

Date	
1 -	Ensoleillé avec passages nuageux. Doux.
2 -	Averses surtout en après-midi. Doux.
3 -	Ensoleillé le matin. Ennuagement en matinée. Averses en fin de soirée. Moins doux.
4 -	Pluie passagère. Devenant venteux.
5 -	Averses de pluie se changeant en faibles averses de neige la nuit. Très venteux.
6 -	Averses de neige fondante se changeant en averses de pluie en fin d'après-midi. Frais.
7 -	Faibles averses de pluie et de neige cessant tôt la nuit. Ciel variable par la suite. Pluie débutant tard en soirée.
8 -	Pluie se changeant en neige en soirée. Venteux.
9 -	Tempête de neige. Frais. Venteux avec poudrerie par moment.
10 -	Ensoleillé. Brins de neige en soirée. Très venteux.
11 -	Brins de neige cessant tôt le matin. Neige débutant en fin d'après-midi. Venteux et frais.
12 -	Neige devenant dispersée le matin. Ensoleillé par la suite. Venteux et frais.
13 -	Ensoleillé. Frais.
14 -	Ensoleillé avec passages nuageux. Plus doux.
15 -	Généralement ensoleillé. Très doux. Venteux.
16 -	Faibles averses de pluie le matin. Ensoleillé en après-midi. Venteux. Beaucoup moins doux.
17 -	Généralement nuageux. Venteux et froid.
18 -	Nuageux avec éclaircies. Moins froid.
19 -	Nuageux.
20 -	Ciel variable. Venteux.
21 -	Pluie se changeant en averses en après-midi. Venteux et frais.
22 -	Pluvieux. Frais et venteux.
23 -	Très faible pluie intermittente. Frais et venteux.
24 -	Averses de pluie cessant le matin. Dégagement par la suite. Moins frais.
25 -	Ensoleillé. Venteux et frais.
26 -	Ciel variable. Venteux et frais.
27 -	Nuageux. Averses isolées. Frais.
28 -	Devenant ensoleillé le matin. Plus doux.
29 -	Ennuagement en après-midi suivi d'un orage en fin d'après-midi. Faibles averses cessant en soirée. Doux.
30 -	Ensoleillé. Moins doux.

Daily summary for April 2000
Montreal/Dorval International Airport

Date	
1 -	Sunny with cloudy periods. Mild.
2 -	Rainshowers mainly in the afternoon. Mild.
3 -	Sunny in the morning. Clouding over before noon. Rainshowers late in the evening. Cooler.
4 -	Periods of rain. Becoming windy.
5 -	Rainshowers changing to light snowflurries during the night. Very windy.
6 -	Wet snowshowers changing to rainshowers by late afternoon. Cool.
7 -	Light rainshowers and snowshowers ending early at night. Variable cloudiness thereafter. Rain beginning late in the evening.
8 -	Rain changing to snow in the evening. Windy.
9 -	Snowstorm. Cool. Windy with blowing snow at times.
10 -	Sunny. Evening flurries. Very windy.
11 -	Flurries ending early in the morning. Snow beginning by late afternoon. Windy and cool.
12 -	Snow becoming scattered in the morning. Sunny thereafter. Windy and cool.
13 -	Sunny. Cool.
14 -	Sunny with cloudy periods. Warmer.
15 -	Mainly sunny. Very mild. Windy.
16 -	Light rainshowers in the morning. Sunny in the afternoon. Windy. Quite cooler.
17 -	Mainly cloudy. Windy and cold.
18 -	Cloudy with sunny breaks. Warmer.
19 -	Cloudy.
20 -	Variable cloudiness. Windy.
21 -	Rain changing to showers in the afternoon. Windy and cool.
22 -	Rainy. Cool and windy.
23 -	Light intermittent rain. Cool and windy.
24 -	Rainshowers ending in the morning. Clearing thereafter. Warmer.
25 -	Sunny. Windy and cool.
26 -	Variable cloudiness. Windy and cool.
27 -	Cloudy. Isolated showers. Cool.
28 -	Becoming sunny in the morning. Warmer.
29 -	Clouding over in the afternoon with one thundershower in the late afternoon. Light showers ending in the evening. Mild.
30 -	Sunny. Cooler.

APPENDIX F

EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS WINTER 1999-2000

CM1589.001

EXPERIMENTAL PROCEDURE FOR THE COLLECTION OF FOG RATES OF DEPOSITION IN NATURAL CONDITIONS

Winter 1999/2000

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro

December 2, 1999
Version 1.0

Experimental Procedure for the Collection of Fog Rates of Deposition in Natural Conditions

Winter 1999-2000

1. OBJECTIVE

The objective of this study is to determine the range of deposition rates that occur naturally in fog.

2. PLAN

Collect fog deposition rates on several occasions in periods of natural fog or freezing fog.

3. PROCEDURE

A precipitation collection pan will be used to measure fog deposition rates in natural conditions. Prior to the start of the test, a collection pan will be coated with Ultra+ Type IV fluid (see flat plate test procedure) and weighed. The pan weight (in grams) and the test start time (hh:mm:ss) will then be recorded on a meteo/plate pan data form. In order to simulate the taxi of an aircraft in fog conditions, the collection pan will be mounted on a stand positioned on the hood of a car. In preliminary trials, the mounted pan will be inclined forward at 20°. Prior to the start of the test, zero the car odometer. The vehicle with the mounted plate pan should then be accelerated to a speed not exceeding 30 km/h for a period of 10 minutes in order to collect precipitation. Following the test, the distance traveled during the test will be recorded along with the test end time in order to calculate the average velocity during the test. Finally, the precipitation pan will be re-weighed in order to evaluate the fog catch.

Pending the results of these preliminary trials, the pan inclination, vehicle speed, and test duration may be modified accordingly.

4. PERSONNEL

One research assistant is required for these tests.

5. DATA FORMS

A Meteo / Plate Pan data form (see Table 1) is required for these tests.

6. EQUIPMENT

- Weigh scale
- Precipitation plate pan
- Test plate mount for vehicle
- Inclinometer
- Type IV Ultra+ fluid

TABLE 1

METEO/PLATE PAN DATA FORM (FOG DEPOSITION TRIALS)

Winter 98/99

LOCATION:	DATE:	RUN # :

PLATE PAN WEIGHT MEASUREMENTS

PAN #	t TIME BEFORE (hr:min:ss)	t TIME AFTER (hr:min)	w WEIGHT BEFORE (grams)	w WEIGHT AFTER (grams)	COMPUTE RATE ($\Delta w * 4.7 / \Delta t$) ($g/dm^2/h$)

COLLECTION PERIOD INFORMATION

TIME BEFORE (hr:min:ss)	TIME AFTER (hr:min:ss)	TOTAL DISTANCE TRAVELED

TEMPERATURE AT START OF TEST _____ °C

COMMENTS : _____

_____

_____

_____

	PRINT	SIGN
WRITTEN & PERFORMED BY :	_____	_____
VIDEO BY :	_____	_____

File g:\cm1514\procedur\fog_dep\Rate_frm 1/16/03, 12:55 PM

APPENDIX G

EXPERIMENTAL PROGRAM
PLAN FOR FROST TESTS ON FLAT PLATES – NORTHERN AIRPORTS
WINTER 1999-2000

CM1589.001

EXPERIMENTAL PROGRAM
PLAN FOR FROST TESTS ON FLAT PLATES - NORTHERN AIRPORTS

Winter 1999/2000

Prepared for

Transportation Development Centre
Transport Canada

Prepared by: John D'Avirro

APS AVIATION INC.

December 3, 1999
Version 1.0

EXPERIMENTAL PROGRAM
PLAN FOR FROST TESTS ON FLAT PLATES - NORTHERN AIRPORTS

December 3, 1999
Version 1.0
Winter 1999-2000

- The ideal conditions for the development of frost are:
  - i) Less than two knots of wind;
  - ii) Clear sky preferred; and
  - iii) Dew point and ambient temperatures comparable.

- Frost tests will be conducted overnight.

- Surfaces to be tested include standard 1/8" aluminium flat plate (Plate A), 1/16" aluminium painted plate [white] (Plate B), honeycomb carbon fibre composite (Plate C), and Kevlar/Aramid honeycomb composite (Plate D).

- Record test surface weights and time prior to placing on a 10° slope (approximately 3.5" high). Place surface such that wind is moving up the plate

- Reweigh the test surface at 1-hour intervals to determine frost deposition.

- Ensure no loss of frost during the reweighing process (i.e. frost does not melt when weighing and placing on table again-do not keep inside for too long).

- Repeat processes for each of the four plates.

TABLE 1

METEO/PLATE PAN DATA FORM

VERSION 7.0 Winter 98/99

REMEMBER TO SYNCHRONIZE TIME WITH AES - USE REAL TIME

LOCATION: DATE: RUN # :

PLATE PAN WEIGHT MEASUREMENTS *

PLATE	t TIME BEFORE (hh:mm:ss)	w WEIGHT BEFORE (grams)	t TIME AFTER (hh:mm:ss)	w WEIGHT AFTER (grams)